THE USE OF CITATION DATA IN WRITING THE HISTORY OF SCIENCE

December 31, 1964

Eugene Garfield, Ph.D., *Director*
Irving H. Sher, Sc.D., *Director of Research*
Richard J. Torpie, *Research Associate*

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TABLE OF CONTENTS

NETWORK CHARTS: FOLLOWING LAST PAGE

1. (Red) First Overlay------Asimov's Specified Historical Connections
2. (Red) Second Overlay--- Asimov's Implied Historical Connections
3. (Blue) Third Overlay---- Coincident Strong Citation Connections
4. (Blue) Fourth Overlay---Coincident Weak Citation Connections
5. (Yellow) Fifth Overlay--Non-Coincident Strong Citation Connections
6. (Yellow) Sixth Overlay--Non-Coincident Weak Citation Connections

I. FOREWORD

Can a computer write the history of science? Probably not in the sense usually implied. However, the research reported herein is a preliminary attempt to understand and define some basic problems that must be solved if computers are ever to aid the historian of science -- no less supplant him. In this study it was necessary to select a recent important scientific breakthrough which was based on the cumulation of years of diverse scientific achievement. For this reason we selected the discovery of the DNA code. For a concise historical description of the events, we then selected "The Genetic Code," a book by Dr. Isaac Asimov which describes the major scientific developments that eventually led to the duplication in the laboratory of the process of protein synthesis under control of DNA.

The choice of the genetic code as our case study was not fortuitous. Major breakthroughs in the field of molecular biology occurred at a time which coincided with the completion of our first extensive experimental citation indexes, the *Genetics Citation Index* (1) and the *1961 Science Citation Index* (2) from which part of the GCI was extracted. The availability of pertinent citation data made practical the testing of citation indexing for constructing historical maps and evaluating individual scientific events.

The history of citation indexing for the purposes of disseminating and retrieving information has been extensively described elsewhere (3). A suggestion for its use in historical research came as early as 1955 (4,5). However, the use of citation data for constructing historical maps was given great impetus by Dr. Gordon Allen when he prepared a bibliographic citation network diagram demonstrating the chronological relationship and citational linkages among a group of papers on the staining of nucleic acids. Allen's citation network diagram provided a useful model of scientific literature and simultaneously provided, in a two-dimensional topological display, the historical development of the subject matter covered by the fifteen papers in his bibliography. (6) The availability of large files of computer-generated citation indexes and the experience derived in their preparation made practical the possibility of testing the usefulness of this approach in studying history.

The methodology developed here will hopefully prove useful to the historian and others interested in tracing the origins of discovery and creativity. It consisted of two steps.

First, we carefully identified the specific papers involved in the discoveries described by Asimov in his history of DNA. The exacting work in tracing all the pertinent citations should be readily apparent from examining the report. From this data we constructed a topological network diagram for 40 milestone events as described by Asimov. Then, we constructed a similar topological network based on citation data appearing in the bibliographies included in the papers reporting the same key discoveries.

The two networks were extensively analyzed and compared and demonstrated a high degree of coincidence between an historian's account of events and the citational relationship between these events. Comparison of the resulting networks has been facilitated by the use of special transparent overlays.

We also created a special citation index file from the references given in the papers reporting the milestone events described by Asimov. We elaborated on this basic corpus of citation data by drawing upon our broader 1961 *Science Citation Index*.

Though this study was undertaken to investigate and test new methodologies for facilitating the writing of the history of science, we do not wish in any way to imply that the role of the scholar can be eliminated. The citation network technique does provide the scholar with a new *modus operandi* which, we believe, could and probably will significantly affect future historiography.

With the accelerating pace and complexity of scientific developments, the study of the history of science, research administration, and the sociology of science, now more than ever, can profitably employ new techniques for sifting and evaluting data. We believe the techniques described here can be of great utility for the administration of large-scale programs of research as well as for sociological and historical research.

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(5) E. Garfield, "Citation Indexes in Sociological and Historical Research," *American Documentation* 14(4), 289-291 (1963).

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II. SUMMARY

Writing the history of science has traditionally been a purely intellectual or cerebral pursuit of the scholar. A project is described herein which poses, and provides the first step toward the ultimate answer to the question "Can historical analysis be performed by a computer?" The more immediate goal was to test the initial hypothesis that citation indexes are useful heuristic tools for the historian. In this approach the history of science is regarded as a chronological sequence of events in which each new discovery is dependent upon earlier discoveries. Models of history are constructed consisting of chronologic maps or topological network diagrams. Two such models were used here. The first is based on the events in the history of DNA as described by Dr. Isaac Asimov in *The Genetic Code*. The second is based on the bibliographic citation data contained in the documents which are the origional published studies of events represented in the Asimov book. The interdependencies of linkages among 40 major events (nodes) included in both network diagrams were carefully mapped and compared.

A novel method was devised for these comparisons. Colored transparencies of the network diagrams, when superimposed, aid in the identification of historical dependencies between events. The red transparencies show those dependencies revealed by the Asimov analysis alone; the yellow transparencies show those dependencies revealed by citation data alone, and the blue transparencies show the dependencies common to both analyses. Connecting lines between nodes were coded to indicate whether the linkages are explicit (in the case of Asimov) and direct or indirect (in the case of citations.)

The analyses, supported by numerous statistical tables and specially constructed citation indexes, show that the original hypothesis is reasonable. Unquestionably, bibliographic citation data, if presented in the form of network diagrams and or citation indexes, reveal historical dependencies which can be easily overlooked by the historian. On the other hand, citation standards are not always sufficiently rigorous to eliminate the need for human memory and evaluation. It is reasonable to conclude that the techniques described in this study can be profitably used in writing the history of science by helping to identify key events, their chronology, their interrelationships, and their relative importance.

In this study we first carefully searched the scientific literature in order to determine the published works which most accurately fit each historical event described by Dr. Asimov. Altogether there were 65 "nodal" articles selected which had been written by 89 different investigators, 48 of whom are explicitly mentioned in Asimov's text. The 40 events, each of which is a node in the historical graph, were categorized and coded in broad subject classifications and arranged chronologically on transparent overlays. To determine citation linkages between nodes, the bibliographies of all nodal articles were

first examined for direct citation to other nodal articles. Less direct citation linkages were also established through chronologically intermediate works by nodal authors, or in a few cases, where these were lacking, through intermediate works by non-nodal authors.

In this study, 65% (28/43) of the historical dependencies in the Asimov network were confirmed by corresponding linkages established by citations. In addition 31 citation connections were found which do not correspond to any historical dependencies noted in "*The Genetic Code.*" Eleven of the nodes did not cite any earlier nodal work. There is thereby highlighted an implication that these 11 nodes introduce new fundamental information into the area encompassed by the network.

A numeric weighting was assigned each node depending upon the number and type of citation connections to and from the node. The highest nodal value found is for a discovery which Asimov described as the most essential contribution to the historical scheme.

The *1961 Science Citation Index* was searched to determine the total count of first-author citations to every work listed for each nodal author. Senior nodal authors (the 48 distinguished by Asimov) were cited 5,329 times in the 1961 literature (a mean of 112 citations per author), while junior nodal authors (those not mentioned by Asimov) were cited 1,706 times (a mean of 41.6 citations per author). In the *1961 SCI* the average reference author is cited 5.5 times while recent Nobel Prize winners (1962 and 1963) were cited an average of 169 times. More senior than junior nodal authors had citations to works published earlier than the date of the nodal work, and generally the earliest cited work for a senior nodal author predated those for junior nodal authors by a mean of nearly 6 years. This chronological positioning is consistent with the concept that senior nodal authors were more "established" by the time nodal papers were published.

In 71 instances in the 1961 SCI nodal authors cited works by other authors of different nodes. These cases provide evidence for a citation "leapfrogging" effect involving spans of many years. In certain cases leapfrogging reinforced already established historical or citational dependencies between nodes. The frequency of leapfrogging by nodal authors increases sharply among the fourteen most recent nodes --- those representing the coalescence of the new field of molecular biology of the genetic code.

The 1961 SCI revealed that in 58 instances a nodal author cited a work by a co-author. Of the 58 citations, 50 involve citations to the most recent twelve nodes.

The number of citations in the *1961 Science Citation Index* to individual nodal articles was compared to those for other articles by the same first author. In a ranked listing half of the cited nodal articles ranked higher than sixth. The nodal work of more than half of the recent (1941-1961) authors ranked as the most heavily cited work for that author. Recent nodal articles also have a higher average absolute count of citations. Therefore not only are nodal authors well cited, but there also exists a strong tendency for their most important works to be cited especially heavily. A special Nodal Citation Index (NCI) was prepared in order to further analyze the bibliographies of nodal papers. In the NCI entries

are repeated for all secondary reference authors, thereby, more easily revealing self-citation patterns and an investigator's possible contribution to one or more other nodes. The NCI also reveals coupling between nodal works which cite the same group of references. This can indicate to what degree any two discoveries are dependent on a mutually shared reference.

The work of twenty-six primary and/or secondary non-nodal investigators found in the NCI was cited by authors of at least three different nodes. Thirteen of these 26 investigators were cited more heavily in the *1961 SCI* than the mean for senior nodal authors mentioned by Asimov. Twenty-five of the 26 are cited more heavily than the mean for junior nodal authors. Therefore non-nodal authors cited by at least three different nodes are also well cited in the 1961 literature and are of comparable rank (as measured by citation count) to the nodal authors themselves. Four of the heavily cited references from these 26 non-nodal authors were selected with the aid of additional criteria and investigated for their historical importance. One such reference definitely had the characteristics of a major breakthrough. The others involved innovations in methodology, a difficult matter to evaluate historically. The experiment indicates how even a limited citation index can aid the historian in discovering works not known by him but which should be considered and evaluated. The historian could also profit by considering possible historical implications between nodes connected by citation linkages.

A special Source Index for all the nodal articles arranged by first author was also prepared. This Source Index gives the full authorship of each paper, article title, type of article, the number of authors and works cited by the source paper, the chronological node number, a brief historical description, country of origin of the work, numeric evaluation of citation relationships, organization where the work was done, supporting grants and the complete bibliography.

Fifty-five percent of the nodal research was performed in the United States. The United States Public Health Service and its National Institutes of Health provided grant or fellowship funds supporting 67% of the more recent nodal works (published since 1946).

The average number of authors per nodal paper (2.15) is not significantly different from the average authorship reported for all biomedical papers. The proportion of nodal papers with only one author (16/65) also was undistinguishable from reported averages. Evidence is presented to demonstrate that nodal authors are heavily cited by non-nodal authors and therefore, are in the mainstream of science, yet a certain degree of "cliquishness" among nodal authors is quantitated.

It is concluded that citational patterns provide a valid and valuable means of investigating historical dependencies. Other studies have been suggested for continued research on this subject.

III. INTRODUCTION

The role of the historian is to describe events and provide perspective on the relationships between events which may seem isolated to the untrained observer.

The reports concerning the assasination of President Kennedy serve well to demonstrate the difficulty of amassing the "facts" of history even of an event which was observed by countless persons. The data have been analyzed by many experts with great investigative talents. And yet there still remains doubt as to what precisely occurred. It is not surprising therefore, that there are always numerous uncertainties in writing even a fragment of the history of science. The writing of history is subject to much human error in spite of the dedication and relatively rigorous standards held by the professional historian. Unlike legal testimony, motivation and the evolution of ideas are all too often omitted from scientific writings. Tracking down pertinent documents also involves well-publicized difficulties. Historical description must therefore fall far short of an ideal. We can only strive to develop methods that bring us somewhat closer to the truth.

Major achievements in science are relatively easily recognized milestones on the road of progress. However, the minor and less heralded contributions are difficult to identify and even relatively important discoveries may be overlooked in the plethora of data to be evaluated. The historian, in describing the progress of science, is limited by his own experience, memory, and the adequacy of the documentation available. His subjective judgement primarily determines the historical picture of the development of events.

Before World War II the historical perspective of science was relatively easy to gauge. The pace of discovery was slower, scientific fields were less crowded, and the time between basic discovery, evaluation, and application was generally more protracted. Today many new technologies have arisen, and organized research continues to grow at an exponential rate. In sifting the voluminous output of this research, there is an increasing possibility that the historian may eliminate the wheat with the chaff. It becomes ever more difficult to identify potentially important contributions and establish criteria of excellence. The historian's task therefore becomes more complex.

The bibliographies contained in most scientific papers represent a brief history of the subjects they treat and lead to earlier related events. These bibliographies may be usefully reassembled by citation indexing methods in a new chronological orientation -- leading to the later related events. However, analyses based on citation counts must be challenged with the question, "What is the relationship between citation frequency and the historical impact or importance of the work cited?" High citation counts reflect impact but may or may not reflect intrinsic worth. The data obtained from citation analysis are always relative rather than absolute.

In a "citational" approach to historical description one must consider the fact that some scientists consciously or unwittingly ignore earlier work -- at least in their bibliographical

data. Our previous experience using citation indexes for information retrieval as well as the results of the present study indicate this factor is of minor significance, at least when utilizing literature published during the past two or three decades. The refereeing system has undoubtedly helped insure that most pertinent bibliographical data are used in published papers. However, what may be lacking in one paper will be provided in another.

Dr. Isaac Asimov, in his book *The Genetic Code*, has clearly and concisely described the interplay of a century of complex research which led to our present understanding of the DNA genetic code mechanisms for directing protein synthesis. Interspersed in his text are descriptions of milestone discoveries in the history of DNA. Each of these events can be plotted as vertices or nodes in a topological network diagram. Dr. Asimov, writing essentially from memory, did not use the original technical papers or their bibliographies. In his book, he describes some of the specific dependencies of linkages between these nodes or events. Other historial relationships between nodes are implicit in the book or evident through careful interpretation.

In this study, we have investigated in depth the correlations that may exist between Asimov's historical analysis of the key DNA discoveries and a similar analysis derived from citation data covering these same discoveries. The investigation, therefore, is an exploratory comparison of two methods of characterizing history (1) conventional or traditional subjective analysis (2) objective citational or bibliographical analysis.

IV. METHODOLOGY

(1) Isaac Asimov's book, *The Genetic Code*, New American Library, New York, 1963, was used as the starting point from which a network schema was constructed which graphically outlines the key discoveries leading to our present understanding of the mechanisms and role of DNA in protein synthesis. (A synopsis of *The Genetic Code* in chapter form is provided for reference in Appendix I). The synopsis has been approved by Dr. Asimov and permission to include the synopsis here was obtained from the publisher, the New American Library.

(2) The key discoveries described by Asimov were plotted as nodes in an historical network schema. Criteria for selection of these nodes from Asimov's text were based on:

(a) A description of discoveries by explicitly named investigators.

(b) A description of discoveries of very obvious importance -- not explictly named by Asimov, but easily identified due to his provision of other data such as date or place of investigation. For example, Jacob and Monod (Node 35) are described by Asimov as scientists at the Institut Pasteur, Paris, who demonstrated the existence of messenger RNA in bacterial cells in 1961.

Events which were vaguely described were excluded as nodes. Forty nodes were established of which 36 were explicitly named and the balance inferred from Asimov's data. The first node, chronologically speaking, is the work of Braconnot in 1820 and the last that of Nirenberg and Matthaei (1962) -- covering about 140 years.

(3) An extensive literature search using conventional bibliographic tools was completed in order to identify citations for the specific published work described by Asimov for each node. The strictest scholarly criteria were adopted to insure not only that the reference coincided with the node, but also that the reference citation chosen was the paper which most definitely corresponded to the discovery in question. These limitations imposed an important restriction since very often a subsequent work extended the applications of the discovery and established citation connections not to be found in the original paper. (See Appendix II). However, 17 out of 40 nodes in the historical diagram actually represent more than one published paper. Stated another way, several of the nodes on the pure citation network have been coalesced to represent a single node on the Asimov network.

(4) Copies of all pertinent articles were obtained along with translations when these were available. Sixty-five articles were required to cover the 40 nodes explicitly or otherwise described by Asimov. (These are listed in Appendix VI.)

(5) The nodes were plotted chronologically and grouped in broad subject classifications such as nucleic acid chemistry, protein chemistry, genetics, microbiology, or pertinent combinations of these disciplines. Asimov's book was then examined to determine the historical relationships between these 40 nodes. The relationships or

connections between the nodes are shown in the first two Network Charts, both of which are colored red. Solid lines on one of the red transparent overlays indicate relationships explicitly specified by Asimov. Broken lines on the other red overlay represent implied relationships. (These charts are folded inside the back cover).

(6) The bibliography of each node article was examined to determine the citation connections between it and other node papers. If it specifically cited any other nodal article, connecting lines for *direct citations* were established on the Network Charts. The bibliographic examination was extended to include somewhat less direct linkages between the nodes whenever other closely related works by authors of the earlier nodal papers could be found. If a particular node could not be linked to any earlier node by either of these methods, other likely citation pathways were examined, such as connection via an intermediate self-citation, and as a last possibility intermediate connections through any other references cited in the later nodal paper. (Detailed connections are described in Appendix II). In order to facilitate analysis, the network is printed on colored overlays or transparencies which when superimposed emphasize instances of verification by citation analysis of the historical relationships established by Asimov in his book. Thus, the blue overlays show the same 40 nodes described in Asimov's book. The blue solid and dotted lines indicate the existence of reference citations in the nodal papers linking two nodes. For example, Mirsky (39) cites Monod (35). The blue lines are citations which are *coincident* with red lines, that is, indicate where the connectivity of two events explicitly or implicitly described by Asimov are also revealed by a special citation index created for the 65 node papers.

Finally, the yellow overlays show citation connections between nodes which are not disclosed by Asimov. The legend for overlays appears as the last appendix, that immediately preceding the transparencies inside the book cover.

(7) A special citation index based on the 65 papers was created so that pertinent connections between nodal papers could be established. The special Nodal Citation Index (NCI) contains all pertinent data for primary as well as secondary authors. (Appendix III).

(8) In a separate bibliography or Source Index each nodal article is listed and arranged alphabetically by first author. Each item is provided with complete bibliographic data such as full authorship, journal, volume, page, year, type of article, number of authors, and works cited (as well as the complete bibliography itself), chronological node number, title, a brief Asimov description of the node, country of origin, numeric evaluations of citation relationships, organization where the work was done and supporting grants. This bibliography is found in Appendix VI.

(9) Separate listings of the nodal articles arranged by supporting agency, by organizational location of work, and by numeric weighting factor representing the degree of citational relationships were also prepared. (See Appendices V, IV, II)

(10) The *1961 Science Citation Index* was searched to determine the total number of citations of every work listed for each nodal author in which he was first author. This information was broken down into self-citations, citations by authors of the same nodes, citations by authors of different nodes and the year of the earliest cited paper. The tabulated material was analyzed to determine if certain authors distinguished by Asimov were subject to citation patterns different from nodal coauthors *not* mentioned by Asimov and who therefore are implied to be less important. The *1961 Science Citation Index* was also examined to reveal any additional citations to nodal authors by other nodal authors. Such data was not incorporated, however, into the overlay sheets. (See p. 7).

(11) The *1961 Science Citation Index* was searched in order to determine the number of citations to each nodal article. On the basis of the 1961 citation counts, the nodal papers were each ranked relative to the other cited works listed for that author. (See p. 15).

(12) The 1961 citation counts for individual papers and authors not mentioned by Asimov (but which were heavily cited in the Nodal Citation Index and therefore might be important) were compared with counts for papers and authors specified by Asimov. The citation relationship between nodal authors within the Nodal Citation Index was also studied. (See p. 23).

V. ANALYSIS OF THE CITATIONS TO NODAL AUTHORS FROM THE 1961 SCIENCE CITATION INDEX

What objective support does one find in citation frequency data for the subjective importance which Asimov attributes to the investigators he singled out in the history of DNA? To answer this question, we examined the 1961 *Science Citation Index* and in general found a positive correlation between citation frequency and inclusion in the network. This correlation is similar to that found in another study by us which shows that Nobel prize winners have unusally high citation counts. A large number of the key discoveries named by Asimov were, in fact, made by Nobel prize winners.

The 1961 *Science Citation Index* was therefore used to analyze citations to authors of nodal articles. There are 89 investigators who served as authors of nodal papers. Asimov, however, mentioned only 48 of these and therefore implies that these men are more important in the scheme of history. For the purposes of this report these men are considered senior authors, while those not mentioned by Asimov (the additional 41 coauthors) are considered junior authors.

It might be expected that, in general, the works of the senior investigators would have been more heavily cited than works by coauthors. In essence, the 1961 *Science Citation Index* was used to examine all citations to the works in which any nodal scientist was first author. The following information is tabulated for each author in Table I.

1. Total number of 1961 citations.
2. Number of citations by non-nodal authors.
3. Number self-citations.
4. Number of citations by nodal coauthors.
5. Number of citations by other nodal authors.
6. The publication date of the earliest paper cited.

TABLE 1

1961 SCIENCE CITATION INDEX CITATIONS TO NODAL AUTHORS

Node	Author	Total Number of 1961 citations	Citations by non-node authors	Self-Citations	Citation by Coauthor	Citation by other Node author	Publication Year earliest Paper Cited
40	*Matthaei JH	4	0	1	3	0	1961
40	*Nirenberg MW	28	26	0	1	1	1956
39	Sibatani A	18	18	0	0	0	1952
39	*Allfrey VE	130	118	11	1	0	1951
39	*Mirsky AE	65	64	0	1	0	1935
39	De Kloet SR	4	3	1	0	0	1960
38	*Novelli GD	32	32	0	0	0	1944
38	Eisenstadt JM	4	3	1	0	0	1959
38	Kameyama T	11	8	0	2	1	1959
37	*Dintzis HM	27	27	0	–	0	1952
36	Bresler A	4	4	0	0	0	1959
36	Diringer R	0	0	0	0	0	–
36	*Hurwitz J	72	65	3	0	4	1952
35	*Jacob F	223	200	20	1	2	1951
35	*Monod J	155	132	2	18	3	1937
34	*Hoagland M	216	204	1	4	7	1954
34	Stephenson ML	10	9	0	0	1	1956
34	Scott JF	22	21	0	1	0	1948
34	Hecht LI	85	82	0	2	1	1954
34	Zamecnik PC	101	95	0	3	3	1945
33	*Kornberg A	343	336	1	1	5	1942
33	Lehman IR	54	49	0	3	2	1956
33	Simms ES	0	0	0	0	0	–
33	Bessman MJ	49	46	1	1	1	1958
32	Grunberg-Manago M	64	61	0	2	1	1953
32	*Ochoa S	165	156	6	0	3	1938
32	Ortiz PJ	5	2	0	2	1	1959
31	*Fraenkel-Conrat H	261	250	5	0	6	1940
31	Williams RC	81	81	0	0	0	1944
30	*Palade GE	449	445	2	1	1	1949
30	Siekevitz P	172	167	0	0	5	1949
30	Porter KR	222	216	6	0	0	1939
29	Michelson AM	99	83	13	3	0	1949

*Senior investigator (mentioned by Asimov)

(continued)

TABLE 1 (cont'd)

1961 SCIENCE CITATION INDEX CITATIONS TO NODAL AUTHORS

Node	Author	Total Number of 1961 citations	Citations by non-node authors	Self-Citations	Citation by Coauthor	Citation by other Node author	Publication Year earliest Paper Cited
29	*Todd AR	21	21	0	0	0	1936
28	*DuVigneaud V	145	144	0	0	1	1930
28	Ressler C	41	36	5	0	0	1953
28	Swan JM	38	34	3	0	1	1952
28	Roberts CW	6	6	0	0	0	1954
28	Katsoyannis PC	41	38	3	0	0	1957
28	Lawler HC	8	6	2	0	0	1953
28	Popenoe EA	27	27	0	0	0	1950
27	*Watson JD	111	105	0	0	6	1950
27	*Crick FHC	118	113	1	0	4	1950
26	*Wilkins MHF	50	50	0	0	0	1951
26	Randall JT	65	65	0	0	0	1930
26	Stokes	11	11	0	0	0	1944
26	Wilson HR	1	1	0	0	0	1957
25	*Hershey AD	170	168	0	0	2	1938
25	*Chase M	18	18	0	0	0	1957
24	*Sanger F	255	245	10	0	0	1943
24	Tuppy H	61	57	0	4	0	1953
24	Thompson EOP	28	24	3	1	0	1954
23	*Pauling L	630	621	8	0	1	1925
23	*Corey RB	17	17	0	0	0	1936
23	Branson HR	4	4	0	0	0	1950
22-21	*Chargaff E	223	223	0	–	0	1931
20	*Avery OT	56	55	0	0	1	1919
20	*MacLeod	15	15	0	0	0	1940
20	*McCarty M	90	90	0	0	0	1945
19	Gordon	56	53	3	0	0	1929
19	*Martin AJP	70	70	0	0	0	1940
19	*Synge RLM	39	34	5	0	0	1939
19	Consden R	79	79	0	0	0	1944
18	*Beadle GW	94	94	0	0	0	1931
18	*Tatum EL	45	45	0	0	0	1932

*Senior investigator (mentioned by Asimov)

(continued)

TABLE 1 (cont'd)

1961 SCIENCE CITATION INDEX CITATIONS TO NODAL AUTHORS

Node	Author	Total Number of 1961 citations	Citations by non-node authors	Self-Citations	Citation by Coauthor	Citation by other Node author	Publication Year earliest Paper Cited
17	*Caspersson T	121	115	6	0	0	1924
17	*Schultz J	62	62	0	0	0	1932
16	*Bawden FC	95	89	6	0	0	1933
16	*Pirie NW	67	67	0	0	0	1931
16	Bernal JD	80	80	0	0	0	1924
16	Fankuchen I	5	5	0	0	0	1933
15,12,9	*Levene PA	147	143	0	3	1	1901
15	Tipson RS	33	27	6	0	0	1939
14	*Stanley WM	18	17	0	–	1	1932
13	*Alloway JL	3	3	0	–	0	1932
12	London ES	7	7	0	0	0	1899
12	Mori T	19	14	5	0	0	1949
11	*Griffith F	19	19	0	–	0	1911
10	*Muller HJ	156	121	35	0	0	1914
10	Dippel AL	5	5	0	0	0	1934
9	Jacobs WA	73	73	0	0	0	1915
8,6	*Fischer E	258	256	0	0	2	1878
7	*DeVries H	5	5	0	0	0	1901
6	Piloty O	13	13	0	0	0	1897
5	*Kossel A	21	20	0	–	1	1888
4	*Flemming W	10	10	0	–	0	1879
3	*Miescher F	6	5	0	–	1	1879
2	*Mendel G	3	2	0	–	1	1865
1	*Braconnot H	1	1	0	–	0	1819
	TOTALS	7,035	6,731	175	58	71	

*Senior investigator (mentioned by Asimov)

A. Comparison of Senior and Junior Nodal Authors

The average number of authors of nodal papers was 2.15. This value is indistinguishable from the over-all average currently reported in the literature*. Sixteen papers in thirteen nodes have single authors (37, 22, 21, 14, 13, 11, 8, 7, 5, 4, 3, 2, and 1). Twenty-seven nodes have multiple authors. In seven of those nodes (40, 35, 27, 25, 20, 18, and 17) all the contributing authors are considered senior investigators, i.e., those mentioned by Asimov. This leaves twenty nodes which contain junior coauthors, i.e., those not mentioned by Asimov. For 17 of these 20 nodes the senior investigators are, indeed, more heavily cited than the junior coauthors. The three exceptions are analyzed below:

Node 29 - Michelson is cited more heavily than Todd(99 vs 21). However, the two men were often coauthors. Michelson was usually listed as first author for a series of heavily cited papers (including the nodal reference).

Node 26 - Randall is cited more heavily than Wilkins (65 vs 50). However, if the two men are compared since 1951 (the date of Wilkins' earliest cited papers while Randall's earliest is 1930), Wilkins would be cited more heavily (50 vs 43).

Node 19 - Consden is cited more heavily then Martin (79 vs 70). However, the principal nodal paper (B19) was cited 23 times, and Consden was the first author.

The senior investigators discussed by Asimov, therefore, are generally more heavily cited than their unmentioned coauthors. Another impression seemed evident regarding the unmentioned coauthors; most were cited more heavily during years following the publication of the nodal articles to which they had contributed.

As a base line for the discussion which follows it should be noted that the average reference author in the 1961 SCI was cited 5.5 times while the 13 Nobel prize winners in physics, chemistry, and medicine for 1962 and 1963 were cited an average of 169 times.

B. Breakdown of the Total Count by Type of Citation

Of the 7,035 citations in the 1961 *Science Citation Index* to all nodal authors:

1. 5,329 citations were to 48 investigators discussed by Asimov -- a mean of 112.0 citations per author.
2. 1,706 citations were to 41 co-investigators -- a mean of 41.6 citations per author.
3. There are only 175 self-citations by 30 of the 89 nodal authors in the entire 1961 SCI. (First author citing first author is a self-citation here) It should be noted that the chronological span for this history is 140 years, therefore, only the more recent nodal authors could possibly be involved in self-citations in 1961. If only authors involved in nodal discoveries since 1935 (Node 14) are considered, the statistic reads 135 self-citations by 28 of the 74 authors. A notable exception in the earlier group is Herman Muller whose work at age 71 spans half a century. Therefore, an analysis of the current self-citation practice and the date of the earliest paper cited provide an obvious measure of the extent of an author's

*Clarke, B.L., *Science* 143:822 (1964) – (See Reference 7, p. ii)

involvement in the history of his field.

4. In 1961 there were 58 instances in which a nodal author cited a work in which one of his nodal coauthors was first author. These citations most frequently involve coauthors of nodes 29 to 40 (or from 1955 to 1961) since 50 of the 58 citations are for this period.
5. There are 71 instances in the 1961 SCI in which nodal authors have also cited various works in which the authors of other nodal works were first authors. This may enable us to provide a new method of demonstrating historical correlations through retrospective analysis.

C. Retrospect: The 1961 Citation of a Nodal Author by the Author of a Different Node

It is possible that two nodal works have no parallel relation to each other until both their contributions were eventually utilized by future investigators. For instance, it is difficult to historically relate nodal work by Muller (10) 1926 and Levene (12) 1929 because of the dissimilarity of their work at a period which had no indication for establishing relevance. It can be assumed also that no citation linkage (or at best a rather tenuous difficult-to-establish citation linkage) exists between the two nodes, that is, node 12 to node 10. Yet in 1961 Muller cites a work by Levene. It must be assumed that a relevance has now been established by Muller, albeit in retrospect.

This example and others may establish a connection where none were demonstrated by Asimov or by citation indexing of the nodal papers. It is important to reiterate that this study could not determine whether in fact citation linkages exist that might have been found with a more comprehensive citation index accumulated across many source years. Other instances however, actually coincide with connecting citation lines shown on the historical network chart. The original chronological relationship is reversed in 31 of the 71 citations which are outlined in detail below.

1. Early nodal authors citing a general work by recent nodal authors in the *1961 Science Citation Index* (underlining of the node number indicates agreement with citation connecting lines between two nodes on the historical network chart):

Hoagland	(34)	cites	Jacob (35)
Ochoa	(32)	"	Hurwitz (36) 2x, Hecht (34), Kornberg (33) 2x
Todd	(29)	"	Kornberg (33), Ochoa (32), Watson (27)
Crick	(27)	"	Nirenberg (40), Jacob (35)
Sanger	(24)	"	Fraenkel-Conrat (31) 2x, Du Vigneaud (28), Swan (28)
Tuppy	(24)	"	Fraenkel-Conrat (31) 2x
Synge	(19)	"	Stephenson (34)
Stanley	(14)	"	Hoagland (34), Watson (27), Crick (27)
Muller	(10)	"	Hoagland (34), Lehman (33), Ochoa (32), Fraenkel-Conrat (31), Watson (27) 2x, Crick (27), Hershey (25), Avery (20), Levene (15)

The chronological relationship is unchanged in 40 of the 71 citations listed below.

2. Recent nodal authors citing a general work of early nodal authors in the 1961 *Science Citation Index* (underlining of the node number indicates agreement with citation connecting lines between two nodes on the historical network chart):

Nirenberg	(40)	cities	Hoagland (34), Siekevitz (30), Hershey (25)
Matthaei	(40)	"	Kameyama (38), Hurwitz (36), Hoagland (34), Siekevitz (30) 2x
Allfrey	(39)	"	Monod (35), Hoagland (34), Zamecnik (34) 2x, Kornberg (33), Palade (30)
DeKloet	(39)	"	Hoagland (34) 2x, Siekevitz (30)
Novelli	(38)	"	Hurwitz (36), Monod (35) 2x, Zamecnik (34), Siekevitz (30)
Hurwitz	(36)	"	Lehman (33), Bessman (33), Grunberg-Manago (32), Ochoa (32), Ortiz (32), Watson (27)
Jacob	(35)	"	Kornberg (33), Crick (27)
Monod	(35)	"	Crick (27), Pauling (23)
Ochoa	(32)	"	Fraenkel-Conrat (31)
Fraenkel-Conrat	(31)	"	Stanley (14)
Todd	(29)	"	Watson (27)
Synge	(19)	"	Fischer (8,6)
Tipson	(15)	"	Fischer (8,6)
Muller	(10)	"	Kossel (5), Miescher (3), Mendel (2)

Analysis reveals 29 instances in which citation connections between two nodal authors (expressed in the 1961 SCI) agree with citation connections formed between the same nodal authors on the historical network chart. Forty-two additional citational connections not found on the historical network chart are also demonstrated.

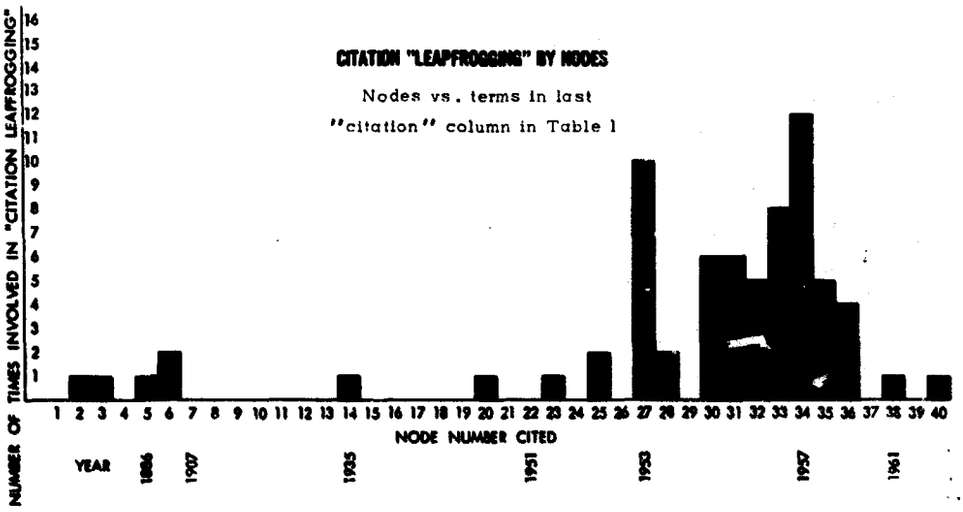
It is important to note here that indirect citation linkages can undoubtedly be demonstrated between nodal papers which, in our blue and yellow transparencies, are not connected. The use of larger citation index files extending over many source years would probably disclose non-nodal "stepping stones" between most of these "unconnected" nodes.

D. Citation Leapfrogging Effect

The chronological relationships in parts 1 and 2 above evidence a citation leapfrogging effect across a span of many years. For example, analysis of nodal papers shows that Hurwitz (Node 36) 1960 cites Ochoa (Node 32) 1955-56; however, in 1961 Ochoa cites Hurwitz (and Hurwitz again cites Ochoa). Other citations between both men may exist and would be discovered by a comprehensive citation analysis of all their works.

Analysis of the frequency with which certain nodal authors are cited in 1961 by other nodal authors is an indication of their involvement in this leapfrogging phenomenon. This frequency (number of times involved) is plotted against the nodal numbers (1 to 40) in the

following histogram. There is a sharp increase of involvement in citation leapfrogging that begins with Watson and Crick (Node 27) whose work, published in 1953, advance an important theory of nucleic acid structure. This increase in frequency coincides with the event which one might intuitively call the coalescence of a new subfield, namely, the molecular biology of the genetic code. This method of recent (1961) citation patterns between nodal authors also appears to pinpoint that event which Asimov as an historian describes as the ". . . model which finally made sense of all the data that had been painstakingly collected on purine and pyrimidine ratios, and which was destined to make immediate sense of the problem of replication . . . "



E. Chronological Position: An Analysis of the Earliest Cited Work by a Nodal Author

The date of the earliest cited work by a nodal author also provides chronological perspective to the nodal paper. Of the 48 senior nodal authors distinguished by Asimov, only four (Chase, De Vries, Miescher, and Kossel) did not have cited works in the 1961 *Science Citation Index* which were earlier than their nodal dates. Eleven of the 41 secondary nodal coauthors were not cited for papers earlier than their nodal dates.

For the 44 senior nodal authors who had earlier works cited the average difference between earliest paper and the nodal paper is 12.4 years, and the median is 11 years.

Similarly, for the corresponding group of 30 secondary nodal authors the average difference is 6.8 years and the median is 5 years. Therefore, senior nodal authors appear to be more "established" than their coauthors by the time nodal papers are published.

From the above results it seems evident that citation indexing objectively supports, with quantitative data, the subjective emphasis that an historian has placed on the contributions of the distinguished authors. Futhermore, many of those involved in past discoveries and who remain active continue to reinforce past nodal author interdependencies in the bibliographies of their most recent works.

VI. ANALYSIS OF THE CITATIONS TO NODAL ARTICLES FROM THE 1961 SCIENCE CITATION INDEX

A. Selection of the Nodal Article

Sixty-five articles are associated with the forty nodes of this study. These were identified after an extensive literature search of the subject and author indexes in *Chemical Abstracts*, *Current List of Medical Literature*, *Cumulative Index Medicus*, etc..

The initial search revealed many candidates for certain nodes. Each candidate paper was critically reviewed in order that the subject content would agree as closely as possible to Asimov's description. Generally, the more difficult choices occurred in papers which were published in the last fifteen years (since 1945) of the period described in Asimov's history. There are two reasons for this difficulty: (1) Lately, communication of a significant discovery is frequently presented in several sources within a very brief period, (2) certain significant contributions involve numerous sequential stages in their evolution and recently the trend seems to be to publish after each stage is completed. This makes it difficult to determine exactly in which paper the concept is originally established or proven. For example the nodal paper for Todd (Node 29) is part 32 in a series.

As a consequence of these difficulties there are certain prerequisites for attempting this type of network study. These include considerable experience and competence in using and searching the literature, and a post-graduate level of training (or its eqiuvalent) in the subjects reviewed by the history. Otherwise, the choice of nodal papers could be poor, introduce serious distortions, and lead to false conclusions.

The limitations imposed by the search-selection are controls required to test the citation network under rigid conditions. For instance, the Watson and Crick discovery of the molecular configuration of DNA consisted of two articles published in the 1953 volumes of *Nature*. The bibliographies contained in these papers were extremely brief and seemingly of little value in demonstrating citation dependency on earlier work. Within the year, Watson and Rich published a brief paper (*Proc. Nat. Acad. Sci. U.S.* 40:759, 1954) on the same subject which, unlike the two previews papers, directly cited nodal articles by Avery et al (20), Hershey and Chase (25), Wilkins (26), and Chargaff (22). There were other papers which also demonstrated many more connections to nodal articles than did the earliest paper which fully described the discovery. The present report, therefore, does not attempt to demonstrate the blunt force of numerous citations from "convenient" papers; it tries rather to analyze the citation linkages which play a more meaningful role in the historical evolution of the subject.

B. Ranking of Citation Counts to the Nodal Article

In the Table 2 the sixty-five nodal articles are listed by their first author. The *1961 Science Citation Index* was consulted to determine the number of citations to each

paper. This figure was compared to the number of citations for other individual papers by the same author in which he was first author, and a relative ranking established.

TABLE 2

Ranking of Nodal Articles Relative to Other Cited Works
by the Same First Author Based on Citation Counts Found
In 1961 (or 1964) *Science Citation Index*

Nodal Articles (Arranged Chronologically)		1961 SCI Number of Citations[1]	Ranking by Citation Count[2]	
1961-2				
Matthaei	A40	30*	1	
Nirenberg	B40	112*	1	(1)
Nirenberg	C40	10*	2	
Sibatani	A39	40*	1	
Novelli	A38	1	> 5	
Eisenstadt	B38	7*	1	
Kameyama	C38	4*	> 1	
Dintzis	37	10	1	
Hurwitz	36	23	1	
Jacob	35	24	1	
Hoagland	A34	27	3	(1)
Hoagland	B34	57	1	
Kornberg	A33	1	5	
Kornberg	B33	2	> 5	(>5)
Kornberg	C33	6	> 5	
Grunberg-Manago	A32	6	4	(2)
Grunberg-Manago	B32	13	2	
Ochoa	C32	2	> 5	
Fraenkel-Conrat	A31	9	3	
Fraenkel-Conrat	B31	11	2	(2)
Fraenkel-Conrat	C31	6	> 5	
Palade	A30	14	> 5	(2)
Palade	B30	43	3	
Michelson	29	3	> 5	

1 Asterisk indicates number of citations in the 1964 SCI.

2 Number in parentheses is rank if citations to papers by the same first author are totaled and treated as one paper.

	Nodal Articles (Arranged Chronologically)		1961 SCI Number of Citations	Ranking by Citation Count [2]
	DuVigneaud	A28	5	> 5
	DuVigneaud	B28	8	3 (2)
	Watson	A27	44	1
	Watson	B27	27	2 (1)
	Wilkins	A26		5
	Wilkins	B26	5	2 (2)
	Hershey	25	31	1
	Sanger	A24	15	4
	Sanger	B24	17	3
	Sanger	C24	24	2 (2)
	Sanger	D24	11	> 5
	Pauling	A23	5	> 5
	Pauling	B23	25	4 (1)
	Pauling	C23	5	> 5
1951				
	Chargaff	22	1	> 5
	Chargaff	21	0	> 5 (>5)
	Avery	20	33	1
	Gordon	A19	1	> 5
	Consden	B19	23	1
	Beadle	18	7	3
1941				
	Caspersson	A17	1	> 5
	Caspersson	B17	1	> 5 (>5)
	Bawden	A16	0	> 5
	Bawden	B16	3	5 (5)
	Levene	15	0	> 5
	Stanley	14	0	> 5
	Alloway	13	2	1
	Levene	A12	2	> 5
	Levene	B12	0	> 5 (>5)
	Griffith	11	10	1

2 Number in parentheses is rank if citations to papers by the same first author are totaled and treated as one paper.

Nodal Articles (Arranged Chronologically)		1961 SCI Number of Citations	Ranking by Citation Count [2]
Muller	10	0	> 5
Levene	A 9	0	> 5 } (>5)
Levene	B 9	1	> 5
Fischer	8	0	> 5
Devries	7	0	> 5
Fischer	6	1	> 5
Kossel	5	0	> 5
Flemming	4	1	2
Miescher	3	1	1
Mendel	2	11	1
Braconnot	1	0	> 5
	TOTAL . . .	674	

TABLE 3

Chronological Summary of Table 2

Nodal Articles Published in the Period	Average Number of Citations per Article (only from 1961 SCI)	Range
1951-1961	15.1	0-57
1930-1950	5.5	0-33
1819-1929	1.1	0-11

2 Number in parentheses is rank if citations to papers by the same first author are totaled and treated as one paper.

TABLE 4

Breakdown of all 65 Nodal Articles
1819-1962

Ranking of Nodal articles relative to other works by same first author	No. of occurrences of each ranking
1	17
2	7
3	6
4	3
5	2
> 5	32

TABLE 5

Table 5 below demonstrates that there are more instances in recent years in which the Nodal article is the most heavily cited work among those for which the Nodal author was first author.

Breakdown of the Most Recent 44 Nodal Articles
1941-1962

Ranking of Nodal articles relative to other works by same first author	No. of occurrences of each ranking
1	13
2	6
3	6
4	3
5	1
> 5	15

The above rankings treat each nodal article separately. However, if name repetitions are excluded and we use the parenthetical values from Table 2, there are only 41 individuals who function as first author within the network. We total the citations for each of the 41 individuals and compare each total to the number of citations given other references by this author. For instance, DuVigneaud's nodal article (A28) was cited five times (Rank 5) in the 1961 *Science Citation Index*. DuVigneaud (B28) was cited eight times (Rank 3). The total of 13 citations (pooling DuVigneaud's nodal articles) would give a new composite ranking of 2. In this sense, both nodal articles are treated as one, and the citation count compared to the number of citations given all other references by the author. This treatment is valid to the extent that later authors will cite only *one* reference out of *several* that have essentially the same context. Furthermore, some of the nodal articles are brief reports of correspondence and herald the subsequent nodal paper containing more substance. For example, articles A16, A19, A23, and A38 are brief preliminary letters which all rank >5.

TABLE 6A

Citation Ranking of Pooled Nodal Papers for 41 Nodal First Authors 1819-1961

Ranking of Nodal articles relative to other works by same first author	No. of occurrences of each ranking
1	18
2	7
3	1
4	0
5	1
>5	14

TABLE 6B

1941-1961

Ranking of Nodal articles relative to other works by same first author	No. of occurrences of each ranking
1	14
2	6
3	1
4	0
5	0
>5	6

TABLE 6C

1819-1941

Ranking of Nodal articles relative to other works by same first author	No. of occurrences of each ranking
1	4
2	1
3	0
4	0
5	1
>5	8

Another adjustment is possible; papers ranked >5 can be excluded if a different first author has written another paper (in the same node) which ranks 1-5. The 1941-61 group would thereupon drop three authors whose papers ranked >5 (Table 6D).

TABLE 6D

Adjusted 1941-1961

Ranking of Nodal articles relative to other works by same first author	No. of occurrences of each ranking
1	14
2	6
3	1
4	0
5	0
>5	3

The three remaining authors whose nodal works ranked >5 in Table 6D are Chargaff, Kornberg, and Michelson who are among the more heavily cited authors in nucleic acid chemistry. Their more current work continues to generate such interest that they are cited more often than references six to ten years old. Also Chargaff and Michelson are editors and authors of recent text references on nucleic acid which are cited very heavily and contain, in essence, a review of their nodal discoveries. The ranks of many nodal articles would be improved if their citation counts were compared to other references occurring only within the period three years before or after the nodal date. For instance, the 1953 Sanger nodal article (C24) receiving 24 citations, ranks second to a 1945 non-nodal reference by Sanger with 84 citations. However, the top ranking article antedates the nodal discovery by about eight years. Therefore, if workable limits (on the basis of highest number of citations in the *Science Citation Index*) can be imposed on dates, there is increased probability of selecting the most significant article by a given author on a given subject.

It is obvious that recent nodal articles in the network (1941-1961) receive a better relative rank than older articles (Table 5) and, also, the more recent references have a higher average absolute count of citations (Table 3). Over fifty per cent of all nodal articles ranked between one and five (Table 4). Table 6B demonstrates that the nodal work of over fifty per cent of the recent (1941-1961) authors ranked as *the* most heavily cited work by that author.

In evaluating the data in Tables 6A to 6D one must keep in mind that there is generally a higher percentage of citations in the SCI for any single year to papers published during the past few years. This is, in part, due to the fact that there is more recent literature that can be cited. Statistical data on the chronological distribution of reference citations can be found in the *Introductions* to the 1961 and 1964 *Science Citation Index*. The use of citation data from any single source year is inevitably biased by the tendency to cite more recent papers.

VII. DISCUSSION OF THE CITATION INDEX PREPARED FROM THE SIXTY-FIVE NODAL PAPERS (NCI)

The complete Nodal Citation Index (NCI) is found in Appendix III. This NCI includes entries for every reference work cited in any of the 65 nodal papers. Following each of the numerous cited references there is a brief identifying description for each citing nodal paper. A *complete* description of every nodal document is provided in the Source Index of Nodal Papers (see Appendix VI).

A. The Nodal Citation Index (NCI) as a Method of Historical Investigation

In contrast to the 1961 *Science Citation Index* which draws exclusively upon source articles published in a single year (1961), the NCI is derived from articles published in various years during the past century. Thus, the NCI is not chronologically restricted. However, the NCI is a derivative of Asimov's text and, therefore, reflects his opinion as to which are the milestone achievements. It was possible however that the papers covered by Asimov cited other important investigators which he does not cite. To investigate this possibility, we determined if non-nodal papers and non-nodal authors heavily cited in the NCI were also heavily cited in the 1961 *Science Citation Index*. The number and pattern of 1961 citations to distinguished nodal authors and articles have been established in the preceding sections. It was of interest to determine if these heavily cited non-nodal authors or papers had comparable patterns.

If so, then certain heavily cited *authors* and *articles* should perhaps have been included by Asimov in his book.

1. Selection of *Articles* Cited by at Least Three Separate Nodes

   The only non-nodal *article* in the NCI that was cited by at least three distinct authors of three separate nodes was:

   Siekevitz P, "Uptake of Radioactive Alanine *in vitro* into Proteins of Rat Liver Fractions," *J. Biol. Chem.* 195,549 (1952). It was cited by Kameyama (38), Nirenberg 2x (40), Palade (39), and Matthaei (40).

Siekevitz also appears as a junior nodal coauthor (not mentioned by Asimov) with Palade (Node 30). His general works received 172 first author citations in the 1961 *Science Citation Index* which is above the mean of 112 citations for senior nodal authors. The 1952 Siekevitz article received 28 citations in the 1961 SCI and was his most heavily cited paper, *as is typical of nodal papers*. Siekevitz's method for dealing with the uptake of radioactive alanine in liver microsome fraction was used (and referred to in three nodal articles) as a step in the experimental procedure--the washing and counting of radioactive protein precipitates. The method described by Siekevitz was obviously useful but from an historical point of view it can be questioned whether this discovery constitutes a major discovery.

TABLE 7

NCI and 1961 SCI Citation Analyses for Non-Nodal Authors Cited by at Least Three Different Nodes

Non-Nodal Authors Cited by Three or More Different Nodes	Nodal Citation Index: No. of Nodes Represented At Least Once	Nodal Citation Index: Number of Times Cited As: First Author	Nodal Citation Index: Number of Times Cited As: Second Author	Nodal Citation Index: Total	Nodal Citation Index: No. of Entries As First Author	1961 Science Citation Index: Number of NCI First Author Entries Appearing in SCI	1961 Science Citation Index: X if any of These Entries Has a 1 or 2 Citation Rank* 1	1961 Science Citation Index: X if any of These Entries Has a 1 or 2 Citation Rank* or 2	1961 Science Citation Index: Number of Citations As First Author	1961 Science Citation Index: No. of 1961 Citations by Nodal Author	1961 Science Citation Index: Publication Year of Earliest Paper Cited
Astbury WT	4	6	0	6	6	3			85	0	1926
Benzer S	3	3	0	3	3	3			135	11	1948
Berg P	3	3	1	4	3	1			99	2	1953
Brachet J	4	7	0	7	7	4			347	1	1931
Carter CE	3	6	0	6	5	4	X(25)		48	0	1945
Cohen SS	3	4	1	5	4	2			186	2	1940
Colowick SP	3	1	3	4	1	1		X(16)	199	0	1942
Davidson JN	4	0	11	11	0	–	Not applicable		101	0	1939
Gros F	4	2	6	8	2	2			136	0	1946
Hammarsten E	3	7	1	8	5	4	X (7)		28	0	1924
Heppel LA	3	6	4	10	4	4			119	0	1939
Hulbert RB	3	3	2	5	3	3	X(65)		86	1	1944
Kirby KS	4	5	0	5	2	2	X(43)	X(28)	118	6	1955
Lipmann F	3	0	4	4	0	–	Not applicable		189	3	1930
Magasanik B	4	3	5	8	2	2			100	2	1948
Markham R	3	7	3	10	5	5	X(50)		247	1	1942
Meselson M	3	0	4	4	0	–	Not applicable		98	3	1957
Potter VR	4	2	9	11	2	1			166	0	1941
Rich A	3	5	2	7	4	2		X (9)	114	4	1951
Roberts RB	3	0	5	5	0	–	Not applicable		128	2	1949
Schmitz H	3	2	1	3	1	1	X(11)		49	0	1920
Sevag MG	3	4	1	5	3	2	X(20)	X(18)	53	0	1934
Spiegelman S	4	1	6	7	1	1		X (4)	78	3	1942
Volkin E	5	4	2	6	4	3	X(18)		90	5	1951
Weiss SB	4	3	1	4	3	3	X(27)		108	7	1955
Zamenhof S	4	9	3	12	8	2			151	0	1940

*Number enclosed in parentheses indicates number of citations

2. Selection of Non-Nodal Authors Cited by at Least Three Separate Nodes.

Aside from a specific paper like the Siekevitz article the *general work* of 26 non-nodal investigators was cited frequently--that is, by at least three separate nodes. (See Table 7). Four of the 26 well-cited non-nodal authors appear only as secondary reference authors, five only as primary authors, and in 17 instances the position is mixed.

a. Comparisons to Nodal Authors

These 26 investigators were studied by examining the 1961 *Science Citation Index*. Their citation counts were compared with citation counts for nodal authors. Thirteen of the twenty-six investigators were cited *more* heavily than the mean (112 citations) value for 48 senior (first) nodal authors named by Asimov. Twenty-five of the twenty-six were cited more heavily than the mean (41.6 citations) for 41 junior nodal co-authors. Thus, the non-nodal authors cited by at least three different nodes are also well cited in the 1961 literature and are of comparable rank (as measured by citation count) to the nodal authors themselves.

Excluding self-citations, it is important to note that only 19 of the 48 senior *nodal* investigators in the NCI (Table 8 below) are cited by authors of three or more other nodes. Therefore, this characteristic does not have absolute importance even among nodal references. Our subjective impression from Table 8 is that those nodal authors who are heavily cited by nodal scientists tend also to be the most generally renowned researchers. Note that 39 of the 48 senior nodal authors are cited at least once by another nodal author.

We note at this point that although self-citations should be eliminated from counts used in evaluating the impact of a scientists' work on others, the self-citation linkage to later work by the same author is completely legitimate and is as valid as any other citation in establishing conceptual continuity of research.

TABLE 8

The Number of Different Nodes Involved at Least Once in the Citation of a Senior Nodal Author

No Nodes	No Nodes Except for Self-Citations	1 Node	2 Nodes	3 Nodes	4 or More Nodes
Beadle	Dintzis	Alloway	Caspersson*	Corey	Allfrey (4)
Braconnot	Du Vigneaud	Bawden	Fraenkel-Conrat	Crick	Avery (5)
De Vries	Flemming	Chase	Griffith	Fischer	Chargaff (6)
Mendel	Kossel	Hershey	Jacob	Hoagland	Mirsky (4)
	Sanger	Muller	Komberg	Hurwitz	Novelli (4)
		Palade	Matthaei	Levene	Ochoa (5)
		Pauling	McCarty	MacLeod	Stanley (4)
		Tatum	Nirenberg	Martin	Watson (5)
		Wilkins	Schultz	Meischer	
			Synge	Monod	
			Todd	Pirie	

*(Example: Some author of each of two different nodes cited Caspersson at least once.)

The 26 non-nodal authors in Table 7 were studied further to determine whether any should have been mentioned by Asimov and thereby become nodal authors. Some of the 26 are prominent in the field of nucleic acids. Chargaff, for example, in his nodal article (Node 22) considers the work of Brachet and Hammarsten as important as that of Avery (Node 20) and Caspersson (Node 17). Chargaff in his nodal paper (22) states that Brachet and Hammarsten were "responsible for the enormous revival in interest for the chemical and biological properties of nucleic."

b. Selection of Potential Nodal Articles

In our analysis of the 1961 SCI Citations to Nodal articles, it was shown that nearly 70% of the more recent (1941-1961) nodal articles were the most (or second most) heavily cited articles for the first author in *the Science Citation Index*. From Table 7, one finds four authors who (1) are cited in the 1961 SCI more than 112 times *and* (2) have published a paper which is cited in a nodal paper *and* (3) is the author's most or second most heavily cited article in the *1961 Science Citation Index*. On this basis, the following four specific papers by Colowick, Kirby, Markham and Rich would have qualified as nodal articles in the historical network. Therefore, these four references were studies in further detail:

1. Colowick S.P. & Kalckar H.M., "The Role of Myokinase in Transphosphorylations. 1. The Enzymatic Phosphorylation of Hexoses by Adenyl Pyrophosphate," *J. Biol. Chem.* 148,117 (1943).

   Abstract: In the Embden-Myerhof pathway of glucose (hexose) metabolism hexokinase catalyzes the following reaction:

   Adenosine triphosphate (ATP) + hexose $\xrightarrow{\text{hexokinase}}$ adenosine (ADP) + hexosemonophosphate.

   If adenosine diphosphate ADP were substituted as the phosphate donor the above reaction would not go to completion. However, if myokinase were added to either system the yield would include adenylic acid (AMP) and hexosemonophosphate, since myokinase, with hexokinase, will catalyze the reaction:

   $$\text{ADP} + \text{hexose} \xrightarrow[\text{hexokinase}]{\text{myokinase}} \text{AMP} + \text{hexosemonophosphate}$$

   On the basis of this phenomenon the authors further investigated the action of myokinase on adenine nucleotides. They describe a reaction called "phosphate dismutation" in which myokinase catalyzes the transfer of a labile phosphate from one molecule to another.

   $$2\ \text{ADP} \rightleftharpoons 1\ \text{ATP} + 1\ \text{AMP}$$

   Sixty per cent of the ADP is converted into ATP and AMP in this simple equilibrium.

CITATION NOTES

Colowick's work was cited by Ochoa (34), Kornberg (33), and Kameyama (38). This specific paper by Colowick was cited by Kornberg (33) and cites one work by a nodal author, Levene (15).

2. Kirby K.S., "A New Method for the Isolation of Ribonucleic Acids from Mammalian Tissues, "*Biochem. J.* 64,405 (1956).

Abstract: Ribonucleic acid (RNA) was separated from various tissues by a method which permitted extraction with phenol and water at room temperature at pH 6.0-7.5. Pancreatic ribonuclease was inactivated by the same phenol treatment. Most important, however, was that deoxyribonucleic acid remained completely insoluble under the conditions used. This allowed that nuclei did not have to be separated from cell preparations. Also, RNA could be extracted from the DNA - Laden Nucleus.

CITATION NOTES

Kirby's work was cited in the Nodal Citation Index by Hoagland (34), Hurwitz (36), Eisenstadt (38), and Sibatani (39). This specific paper by Kirby was cited twice by Hoagland and was apparently essential for his method. Kirby's paper does not cite any nodal authors.

3. Markham R., Smith J.D., "The Structure of Ribonucleic Acids."
1. Cyclic Nucleotides Produced by Ribonuclease and Alkaline Hydrolysis, *Biochem. J.* 52,552 (1952).

Abstract: The authors state that ribonuclease degradation of RNA polynucleotide discriminates between purine and pyrimidine nucleotides while alkaline hydrolysis does not. Ribonuclease can be used with easily controlled reactions to provide sufficient nucleotides for study and determination of their structure, and also their sequence in the chain. Electrophorectic methods are discussed.

CITATION NOTES

Markham's work was cited by Michelson (29), Ochoa (32), and Sibatani (39). This specific paper was cited by Ochoa (32). The paper cites works by nodal authors Todd, Levene, and Kornberg.

4. Rich A., Davies D.R., "A New Two Stranded Helical Structure: Polyadenylic Acid and Polyuridylic Acid," *J. Am. Chem. Soc.* 78,3548 (1956). [Letter to Editor].

Abstract: Strands of synthetic polyuridylic acid when mixed with strands of synthetic polyadenylic acid formed a helical structure (studied by X-Ray diffraction) containing two strands, one of each type, of nucleic acid. This for the first time shows that RNA can arrange itself in a structure similar to DNA which could account for RNA replication in plant and smaller animal viruses (which contain no DNA).

CITATION NOTES

Rich's work was cited by Ochoa (32), Hoagland (34), and Nirenberg (40); the specific Rich paper cites three node papers: Watson and Crick (27), Wilkins (26), and Ochoa (32).

e. Evaluation of Potential Nodes

The papers by Kirby and Markham are cited for their method. The method by Kirby as described by Hoagland represents a very significant improvement since by Kirby's method RNA could easily be separated from DNA even in the nucleus. The methods described by Markham, at least as indicated by those citing him may not be considered a 'major' contribution. The Colowick paper describes the original instance of *in vitro* enzymatic phosphorylation of a nucleotide (ADP $\longrightarrow$ ATP), and is cited for this reason. The paper by Rich has the characteristics of a major breakthrough since it describes a

phenomenon which might explain replication of RNA virus -- an enigma which challenged the entire DNA theory. The paper by Rich would seem to qualify for inclusion as a node. The papers by Kirby and Colowick are important but are not as clearly essential to the network. The paper by Markham appears even less essential to this particular network, though, its general value might be considered of greater importance in a history of biochemistry. However, it is not easy to evaluate the historical contribution of methodological discoveries. Methodology, of course, provides the tools for discovery. Carter, Magasanik, Sevag, Volkin and others of the 26 heavily cited non-nodal authors are cited on the basis of their innovations in methodology. Consequently, it appears that it may be useful to construct historical networks of science in such a fashion as to easily characterize the method papers. Perhaps insufficient importance has heretofore been attributed to methodology in writing the history of science. Certainly, in the history of technology, methodology should prove to be an even more important factor.

3. Coupling of Nodal Articles as Demonstrated in the NCI.
   As a side excursion into bibliographic coupling we examined one example where non-nodal articles are cited by the same two nodes (32 and 33). Asimov has stated that Ochoa (32) and Kornberg (33) did related work, and indeed they cite each other. Both shared the 1959 Nobel Prize in Medicine and Physiology.
   In the Nodal Citation Index, 19 authors were cited by Node 32 alone, 14 authors by Nodes 32 and 33, and 37 authors by Node 33 alone. We point out the possibility of extending the coupling study to a full evaluation of all the combinations of two and three nodal papers and comparing the quantitative results with subjective and historical impressions of "relatedness" of papers.
4. Intermediate References Used in Indirect Citation Connections
   In all cases of indirect citation whether strong or weak (broken lines on blue or yellow overlays) non-nodal journal references were used as intermediate papers in establishing indirect citation connections between the indicated pairs of nodes on the historical network chart. As it turned out, none of the intermediate references we examined could be used as intermediates between any nodes other than the one pair under consideration.

B. Historical Network Chart

Examination of the overlays demonstrates the number of various types of connections between nodes which have been described in the text. (Consult legend on page 74.)

Asimov's Historical Connections	Specified	29
	Implied	14
	TOTAL	43
Coincident Citation Connections	Direct	15
	Strong Indirect	7
	Weak Indirect	6
	TOTAL	28
Non-Coincident Citation Connections	Direct	10
	Strong Indirect	16
	Weak Indirect	5
	TOTAL	31

Thus, there is citation coincidence found in 28/43 of Asimov's historical connections or a coincidence of 65 per cent. These are represented by blue lines. There are 31 additional non-coincident nodal citation connections whose meanings range from perfunctory acknowledgment of an earlier work to a strong dependency on the earlier work not described by Asimov. We note that there are 29 historical connections specified by Asimov and a similar value of 25 (15 +10) instances in which one node directly cites another.

It might be interesting to examine an historical narrative based on a description of the direct citation linkages and compare that essay with Asimov's original version.

C. Lack of Early Citation Dependency and Scientific Originality

The Historical Network Chart also includes eleven papers which might appear to involve no citation dependency on any earlier nodal papers. Only three of the eleven are assigned specific early connections by Asimov; and only one has an earlier implied historical connection. Therefore, seven of the eleven papers are confirmed as starting points which, within this network, have neither a citation nor historical dependency on earlier works. Each of these eleven papers proved to involve highly original work.

Node *Discovery Reported*

(1) Braconnot isolates the first amino acids.

(2) Mendel demonstrates the laws of inheritance.

(3) Miescher isolates nucleic acid.

(6) Fischer and Piloty determine the structure of ribose, later found to be the carbohydrate fragment of nucleic acid.

(7) De Vries expresses the concept of natural mutation.

(10) Muller produces mutations with x-rays.

(11) Griffith demonstrates bacterial transformation.

(14) Stanley crystallizes virus.

(19) Martin and Synge develop the powerful analytical method of paper chromatography for application in protein chemistry.

(23) Pauling and Corey demonstrate the helical structure of protein.

(26) Wilkins analyzes nucleic acid by X-ray diffraction.

These works (Nodes 1,2,3,6,7,10,11,14,19,23 and 26) appear to represent key breakthroughs which either present new fundamental information in the evolving field or describe new applications of information from other disciplines. The network that can be derived from an account by an historian highlights those events which that historian considers as fundamental. The lack of backreaching historical reference made evident by the drawing of an historical network facilitates a reevaluation of the historian's assumption of fundamentality. In addition to a subjective reevaluation, one may try to confirm or contradict the assumptions of fundamentality by looking for citation linkages from these "fundamental papers" back to other nodal works. Of course, the earlier a work appears in the chronological network, the less likely it is that one will find citations back to other nodal papers.

VIII. CONCLUSIONS

(1) The senior investigators responsible for the nodal papers examined in this study are, on the average, cited in the 1961 *Science Citation Index* with a frequency (112 citations/author) that compares with those for recent winners of the Nobel prizes in science (169 citations/author). Both frequencies are well above the average value (5.51 citation/author) encountered in the 1961 *Science Citation Index*. The frequency of 112 citations/author is observed even though many of the nodal papers involved, antedate the 1961 *Science Citation Index* by many years. "Important" work continues to be well cited long after its publication.

(2) Secondary authors of nodal papers were themselves highly cited in the 1961 *Science Citation Index* (as primary authors of other papers) but were cited less than half as frequently (41.6 citations/author) as senior investigators.

(3) The above confirms a general impression that senior investigators are first authors for their major works. In our study, even the total number of citations (1,706) to all the nodal co-investigators is only 32% of all citations (5,329) to Asimov-distinguished senior nodal investigators.

(4) The chronological position in the 1961 *Science Citation Index* of an author's nodal paper relative to his other cited works indicates that senior nodal authors are well "established" and coauthors to a lesser degree by the time the nodal papers are published.

(5) The citations in the 1961 *Science Citation Index* to the total authorship of the nodal papers include only about one-third the number of self-citations attributed to the average author in the base file.

(6) The bulk (96%) of the total citations in the 1961 *Science Citation Index* to nodal authors was by non-nodal authors. This fact demonstrates that the works of these nodal authors are in the mainstream of science and do not constitute a completely esoteric subgroup of papers. However, we note here the opportunity of developing a quantitative measure of the degree to which the works of a group of authors constitute a clique or "in group." For instance, there are 89 unique authors involved in the nodal papers in this study. There are a total of 57,800 unique primary source authors in the 1961 *Science Citation Index*. The nodal authors therefore constitute 0.154% of the source authorship in the index. Nodal authors appear as primary citing source authors 304 times as having cited nodal reference authors. The total number of citations to nodal reference authors was 7,035; thus, there were 4.32% of intragroup citations to all the works of nodal authors. The fraction of "in group" citations divided by the fraction of total authors (4.32 ÷ 0.154 = 28.0) may be used as a simple approximation of the degree of citation cliquishness. This value should be about one if a given group of authors were engaged in random mutual citation.

(7) The average number of authors per nodal paper (2.15) is not significantly different from the average authorship reported for all biomedical papers. The proportion of nodal

papers with only one author (16/65) also was indistinguishable from reported averages.

(8) Evidence is presented demonstrating a citation leapfrogging effect across a span of many years. This effect may merely indicate an awareness by nodal authors of related work but may also constitute objective evidence for the idea that scientific achievements depend on previous advances. The frequency with which nodal authors are involved as references in the citation leapfrogging is plotted against the nodal paper numbers in a histogram. There is a sharp increase of involvement in citation leapfrogging that begins with Watson and Crick whose nodal paper (27), published in 1953, advances an important theory of nucleic acid structure and may mark the coalescence of a new field of study, the molecular biology of the genetic code.

(9) Nodes 1, 2, 3, 6, 7, 10, 11, 14, 19, 23 and 26 highlight what we would subjectively consider to be the key breakthroughs which present new fundamental information in the evolving field or carry over vital information from other disciplines. The network that can be derived from an account by an historian highlights those events which that historian considers as fundamental. The lack of backreaching historical reference made evident by the drawing of an historical network facilitates a re-evaluation of the historian's assumption of fundamentality. In addition to a subjective re-evaluation, one may try to confirm or contradict the assumptions of fundamentality by looking for citation linkages from these "Fundamental Papers" back to other nodal works.

(10) It has been demonstrated that the nodal work of nearly fifty per cent of the recent (1941-1961) investigators was the most heavily cited work in the 1961 *Science Citation Index* for the investigator who was first author. If articles which were the second most heavily cited work were included, the figure would increase to seventy per cent. Therefore, there may be value in using citation indexing as a tool for identifying those works by an author which are of historical significance. In nearly every exception to the above correlation, the most cited work post-dated the nodal work. This gives the impression that a later work (presumably on the same subject) provided a broader, more useful description of the nodal work and therefore is more often cited.

Citation Indexing of Nodal Bibliographies (NCI) Revealed the Following Facts:

(11) In twenty-six instances, non-nodal authors were cited by three or more different nodes. Half of the 26 investigators were cited in the 1961 *Science Citation Index* more heavily than the mean for senior nodal authors and 25 of the 26 were cited more heavily than the mean for junior nodal authors. The well-cited works of 4 of the 26 non-nodal authors were examined disclosing at least one new paper worthy of inclusion in the historical network. The historian might therefore profit by similar considerations for nodal citation indexes which can be created for histories of other scientific topics.

(12) Fifty-five per cent of the nodal research was performed in the United States.

(13) There were no appreciable number of extramural Public Health Service grants earlier than about 1946. Only the work involved in the later nodes (nodes 21-40) therefore could have been supported by P.H.S. funds. These 20 nodes involved 40 papers. Of these, twenty nodal papers (involving nine distinct nodes) explicitly acknowledge P.H.S. support. (See Appendix V.) In addition, Dintzis (Node 37) had a P.H.S. grant at the time of the work of his nodal paper though it was not acknowledged.

Further, one of the authors, Eisenstadt, involved in Node 38, had a P.H.S. fellowship at the time. Node 38 involves, however, three different papers. Furthermore, the research covered by three papers by Matthaei and Nirenberg in Node 40 were done at N.I.H. in Bethesda. Therefore, 12 of the 20 nodes which postdate 1946 were supported to some extent by U.S.P.H.S. This support involved 27 of the 40 papers comprising these nodes. Thus, the U.S. Public Health Service supported about two-thirds of the appropriate recent nodal work.

(14) This report also demonstrates a 65% coincidence between historical dependencies and the most straightforward citational dependencies. There are many instances where additional non-coincidental citation relationships exist between nodes.

(15) It is felt that citation analysis has been demonstrated to be a valid and valuable means of creating accurate historical descriptions of scientific fields, especially beyond the first quarter of the twentieth century when bibliographic citation had become well established as part of scientific publication.

APPENDIX I

SYNOPSIS OF THE BOOK, "THE GENETIC CODE" BY ISAAC ASIMOV

INTRODUCTION*

In the history of science certain key discoveries, often based on a single profound observation, have opened the way to even greater strides in scientific knowledge. One such discovery was made by Avery et al (20) in 1944. They observed that deoxyribonucleic acid (DNA) carried genetic information which was capable of transforming one strain of bacteria to another different strain, that is, the strain from which the DNA was extracted. This brief story of the genetic code will attempt to explain the significance of Avery's discovery for the field of biochemistry, genetics, and molecular biology.

CHAPTER I

For centuries man was cognizant of only the very obvious features of inheritance. Gregor Mendel (2) in the 1860's first demonstrated the predictability of dominant and recessive traits in plants, and thereby established the first laws of inheritance. Late in the 19th century histologists also studied the phenomenon of mitosis by which a cell, through division, is able to produce a replica of itself. In 1880 Walther Flemming (4) described the replication of paired chromosomes within the cell nucleus which preceded each mitotic division. Each new cell after division contained the same number and type of chromosomes possessed by the original cell. This constancy of chromosome replication throughout lifelong somatic cell division provided some indication that the chromosomes could carry information which determined the properties of each new generation of cells. The role of unpaired chromosomes in germ cell maturation and fertilization provided further evidence that the chromosome was the site of genetic information. The chromosome contains strings of genes. Each gene governs or specifies a particular characteristic of the future organism. The concept that spontaneous alteration of the chromosome can endow the organism with mutant characteristics was first expressed by Hugo de Vries (7) in 1900.

CHAPTER II

The chromosome is largely protein in nature and is conjugated to nucleic acid (nucleoprotein). Nucleic acid was first isolated by Friedrick Miescher (3) in 1869. However, until recently, biochemists believed that genetic information was carried by the protein component of the chromosome. In 1935 Wendell Stanley (14) isolated crystals of tobacco-mosaic virus. The virus, a parasitic invader of the cell, is able to replicate itself within

*(Numbers in parenthesis are node designations). Authors in parenthesis are those not mentioned by Asimov, but who were identifiable by other descriptors. They are considered as senior nodal authors.

the cell as does the chromosome. In 1936 (Bawden & Pirie) (16) discovered that the virus, was also nucleoprotein. Therefore, by 1940 it was known that two different nucleoprotein entities were capable of replication.

CHAPTER III

A review of basic organic chemistry.

CHAPTER IV

Proteins, long considered the "stuff of life", are macromolecules consisting of chains of component amino acids. Braconnot (1) in 1820 was the first to isolate specific amino acids from protein. Any or all of twenty-two amino acids, occurring in any number or sequence, form the building blocks of a virtually unlimited variety of proteins. Emil Fischer (8), between 1900-1910, demonstrated the peptide chemical linkage of chains of amino acids forming a protein.

CHAPTER V

The structural description of protein must account for: (1) Its amino acid components and their sequence; (2) Its bending due to the formation of weak hydrogen bonds between segments of the polypeptide chain, and (3) The precise folding of the chain in space.

Attempts at determining the amino acid sequence of various proteins met with failure for many years. However, Martin and Synge (19) in 1944 developed the method of paper chromatographic separation of amino acids which provided a convenient means for isolation and analysis of protein components. Using this technique and a method of partial fractionation, Frederick Sanger (24) by 1953, was able to determine the amino acid sequence of insulin. Vincent Du Vigneaud (28) used Sanger's technique to determine the amino acid order of two other protein molecules, oxytocin and vasopressin; however, he proceeded one step further by synthesizing these proteins from the necessary amino acids.

Each type of protein formed by the organism is reproduced faithfully from specific types and numbers of amino acids, and in an inflexible order. This presumes a set of coded instructions which allows only select protein construction -- not randomization.

CHAPTER VI

The chromosome seemed endowed with the blueprint for protein manufacture. Possible alteration of the chromosome by artificial means seemed the method of choice for studying this characteristic. Herman Muller(10), as long ago as 1926, was able to produce altered genes and mutants with x-rays. Beginning in 1941 Beadle and Tatum (18) subjected bread mold to X-rays and succeeded in producing mutant molds which required precise amino acid supplementation to the normal growth culture media of sugar and salts. They demonstrated that the X-rays altered a specific mold gene which controlled the manufacture of a specific enzyme (protein) used by normal mold to manufacture the amino acid from unsupplemented media. This assumption led to the one-gene-one-enzyme theory. Belief persisted that the gene might contain a reference protein (protein code) which was in fact the same as the protein (or enzyme) whose production was controlled by the gene. However, this reference

protein was never demonstrated nor was the existence of the complete series of 22 amino acids, common in the adult, ever demonstrated in totipotential germ cells.

In 1928 it was shown (by Frederick Griffith) (11) that a strain of dead *capsulated* pneumococci, added to a culture of *living* non-capsulated pneumococci, could bring about the production of *living capsulated* bacteria. In 1931 (Alloway)(13) it was possible to achieve this transformation with an extract of the dead capsulated bacteria; therefore conclusive proof was presented that genetic material from a dead strain was influencing the characteristics of a live strain. Refinements of this genetic extract were sought until 1944 when Avery, Mac Leod and McCarty (20) identified the extract as protein-free DNA. This work conclusively proved that the genetic code could be carried by nucleic acid alone -- a fact whose impact would influence many disciplines of the life sciences.

Investigations turned to the phenomenon of replication of the virus. In 1952 Hershey and Chase (25) used tagged tracer methods to show that only the nucleic acid portion of bacteriophage virus entered the cell -- not the protein shell. However, while within the cell, the virus replicated itself many times over as a complete entity (nucleic acid and protein shell). This proved that: (1) nucleic acid, even from a virus, was able to replicate itself, and (2) that the viral nucleic acid was able to utilize the native amino acids within the cell to create a protein (the viral shell) foreign to the cell. In 1955 Fraenkel-Conrat (31) was able to separate the nucleic acid and protein shell of tobacco-mosaic virus. The nucleic acid by itself showed little infectivity to tobacco leaf; however, when recombined with its protein shell the virus again became infective. The protein therefore served as a protective capsule to the essential nucleic acid. These discoveries left no doubt that nucleic acid did indeed carry the genetic code.

CHAPTER VII

Fortunately, much of the chemical groundwork was in progress for over half a century prior to the revelation that DNA alone carried the genetic code. The purine and pyrimidine content of nucleic acid was studied by Kossel (5) and others during the 1880's. About 1910 Phoebus Levene (9) identified the five carbon sugar ribose as the carbohydrate component of nucleic acid (Ribonucleic acid, RNA). Ribose had previously been isolated and synthesized by Emil Fischer (6) as a freely occurring sugar. Later Levene (12) discovered that certain nucleic acids contained deoxyribose (DNA). Nucleic acid therefore contained either ribose or deoxyribose exclusive of all other sugars. The combination of (1) purine (adenine or guanine) or pyrimidine (thymine (only in DNA), uracil (only in RNA) or cytosine); (2) ribose or deoxyribose, and (3) an attached phosphate group, was called a nucleotide. Levene (12) theorized that four of these nucleotides, each characterized by a different purine or pyrimidine group, formed nucleic acid (tetranucleotide theory). Levene (15) later proposed formulas which assigned definite linkages between the nucleotides. These were confirmed through chemical synthesis by Alexander Todd (29) in the early 1950's.

CHAPTER VIII

Levene's concept that only four nucleotides formed the nucleic acid molecule was based on crude methods of chemical separation of these entities. Milder extraction methods were used in the 1940-50 period and it became evident that a nucleic acid molecule (or the gene) might be formed of a chain of up to two thousand nucleotides. The demonstration by Avery et al (20) that DNA could carry genetic information made biochemists realize that the tetranucleotide hypothesis was invalid. The Martin and Synge discovery (19) of paper chromatography gave nucleic acid chemists the tool they required to properly analyze the makeup of nucleic acid. Erwin Chargaff (21), by 1947, demonstrated that purines and pyrimidines were present in unequal quantities within nucleic acids; also the ratio of one nucleotide to another differed from one nucleic acid to another. By the early 1950's Chargaff (22) was able to demonstrate that the different nucleotides in the chain were in random order. Therefore they could exist in great varieties of combinations -- at least a sufficient enough number to determine a code for the amino acid order and content of hundreds of thousands of different proteins.

Watson and Crick (27) in 1953 employed X-ray diffraction methods for studies of nucleic acid. These methods were developed by Wilkins (26). They were able to construct a model of the spatial molecular configuration of DNA. This consisted of an interlocking helical arrangement of two polynucleotide chains about the same axis. The helical arrangement of polynucleotide chains had been considered a distinct possibility since Pauling and Corey (23) in 1951 presented the concept that polypeptide chains (of protein) could arrange themselves in a helical configuration through hydrogen bonding. The Watson-Crick model of DNA helped verify previous chemical data and, furthermore, provided a basis for understanding the replication of DNA on a molecular level.

CHAPTER IX

The hydrogen bonding of the polynucleotide strands of the double helix exists at the position of a purine-to-pyrimidine approximation of the two strands. In DNA the purine adenine (A) will always attach to the pyrimidine thymine (T) (however in RNA uracil replaces thymine); further, the purine guanine (G) will always join the pyrimidine cytosine (C). Therefore, any approximate portions of the two strands are opposite and complementary (A-G-T-C vs. T-C-A-G). When the strands separate, each will act as a model for the recreation of the original complementary strand from individual nucleotides. Thus replication can be explained on a molecular basis.

Scientists sought to control methods of biochemical synthesis of nucleic acid. Severo Ochoa (32) in 1955 isolated a bacterial enzyme which produced polynucleotide strands of an RNA variety from adenosine diphosphate. Arthur Kornberg (33) in 1956 produced synthetic polynucleotides of a DNA type from an enzyme, various deoxynucleotides and a

DNA "priming" strand. (The work of Ochoa and Kornberg closely approximated each other in time and scope. Both shared the 1959 Nobel prize. It is the only instance in the network diagram where each man is cited by the other.)

CHAPTER X

Experiments dating back to the early 1940's have shown that invariably the RNA concentration is highest in cells when the rate of protein synthesis is highest (1938 study by Caspersson and Schultz) (17). However, DNA is found only in the nucleus. Most of the RNA is contained in the cytoplasm (the site of protein synthesis), except for a small amount in the nucleus, which is that RNA most recently formed by the DNA of the nucleus. The code from a particular gene (DNA) forms a specific RNA which reaches the cytoplasm to control production of a specific protein. The DNA in this sense is the ultimate prototype of the protein.

The electron microscope and ultra cell centrifugation methods permitted investigation of the cytoplasmic microsomes which were rich in RNA and proved to be the site of amino acid incorporation into protein.

In 1953 George Palade (30) distinguished yet smaller particles associated with the microsomal fraction. He later isolated these particles or ribosomes and found they contained all the RNA of the microsomal fraction of the cell together with an equal amount of protein. Ribosomal RNA is therefore the exact site of protein synthesis but it does not carry the coded genetic instructions of DNA; rather it is the structural backbone, the "key blank", as it were, that could be impressed into service if it could be modified by a second RNA which *does* receive the imprint of the genetic code from DNA. The existence of this second RNA (Messenger RNA) was concluded in 1960 from investigation of bacterial cells (Jacob and Monod) (35). Messenger RNA was isolated from mammalian cells by Mirsky and Allfrey (39) in 1962.

CHAPTER XI

The genetic code consists of trinucleotide combinations or "triplets" running the length of the polynucleotide chain with each triplet representing a particular amino acid. Since there are 64 triplet possibilities and only 22 amino acids, some amino acids may be represented by more than one triplet. Therefore the code is said to be "degenerate". The triplet code does not overlap.

Mahlon Hoagland (34) in the late 1950's discovered that amino acids were combined with adenylic acid in an energy rich combination ("activated amino acid") before being incorporated into the polypeptide chain. Hoagland demonstrated a third type of RNA (freely soluble as short strands in the cytoplasm) which he termed Transfer RNA. Each strand of Transfer RNA consisted of a particular triplet with a code affinity to a particular type of activated amino acid. These combine and attach to a specific position on Messenger RNA where a complementary triplet exists. Dintzis (37) in 1961 demonstrated that this concept of protein construction was accurate. He demonstrated that all the amino acids in a

molecule of hemoglobin could be set in place and bound together in a mater of 90 seconds. The whole scheme was duplicated in a laboratory with the use of cell fragments. In 1961, Hurwitz (36) used a system of DNA, nucleotides, and enzymes and succeeded in manufacturing Messenger RNA in a test tube. Novelli (38) in 1961 carried the process one step further by using DNA nucleotides and also ribosomes and amino acids. He succeeded in manufacturing Messenger RNA which in turn coated the ribosomes. This combination acted as a model for the formation of a particular protein, the enzyme, beta-galactosidase.

The ultimate verification of the triplet code theory came in 1961 when Nirenberg and Matthaei (40), using Ochoa's synthetic method, formed a polynucleotide containing just one polynucleotide, polyuridylic acid. This synthetic Messenger RNA thereby consisted of a chain of triplets with the code U-U-U. In a system containing a variety of amino acids a protein was formed which utilized only one amino acid -- phenylalanine. Therefore, the triplet U-U-U- meant phenylalanine. This discovery is the first step in the ultimate understanding of the genetic code. Its consequences will be left to future history.

APPENDIX II

DETAILED DESCRIPTION OF NODAL CITATION CONNECTIONS AND WEIGHTINGS IN THE NETWORK CHARTS

METHOD A. Bibliographies of nodal articles were searched for citations to earlier nodal authors. The following methods of search were used to demonstrate relationships.

1. Each bibliography was searched for *direct citation* of another nodal paper. Example: Smith 1960 to Jones 1940. *(Strong Direct)*
2. Each bibliography was searched for citations to non-nodal papers by nodal authors which were published subsequent to the cited author's nodal paper. Example: Smith 1960 *through Jones 1950* to Jones 1940 *(Strong Indirect)*.
3. The texts, footnotes, and bibliographies of nodal papers were searched for descriptions of earlier nodes in which a nodal author was acknowledged although no exact reference citation was given. (Weak Indirect). (When a more direct connection was established between two particular nodes, any less direct connection between the two nodes was ignored.)

METHOD B: In a few instances the above methods did not provide connections leading *from* a node to any earlier node. In these instances the following methods were used.

4. The bibliographies of nodal papers were searched for self-citations involving any nodal co-author including those not mentioned by Asimov. The bibliographies of these self-cited references were examined for citation to a prior node. Example: Smith 1960 *through Smith 1950* to Jones 1940. *(Strong Indirect Self-Citation)*.
5. If this failed the following method was used. Each bibliography of *every* reference cited in the node article was searched for citations to earlier nodes. Example: Smith 1960 *through Brown 1950* to Jones 1940. *(Weak Indirect.)*

The term *strong* as applied to citation connections is used here to indicate a citation pathway established directly, or indirectly through use of intermediate papers by the same nodal authors.

The term *weak* as applied to citation connections is used here to indicate a citation pathway established through use of intermediate papers by non-nodal authors. The term weak also implies the use of incomplete citation data such as personal communication, incomplete text reference, etc. as a connecting link.

It should be carefully noted that the possible importance,in the total historical picture, of these non-nodal intermediates is not implied by the word "strong", nor is it denied by the use of the word "weak".

The procedure used in METHOD B above (using intermediate non-nodal authors,

Nodal Weighting Values

An arbitrary weighting factor is assigned each node as an expression of the strength of total citational connections of the node. This binary term is calculated as the sum of the weights of each citational connection entering or leaving the node. A strong direct citation (solid blue lines, 3rd overlay from the bottom, and solid yellow lines, 5th overlay from the bottom) is given a value of 4, a strong indirect citation (broken lines 3rd and 5th overlays) is given a value of 2, and a weak indirect citation (solid or broken blue lines, 4th overlay from the bottom, and solid or broken yellow lines 6th overlay from the bottom) is given a value of 1. The nodal articles are ranked in the following list wherein the paper by Devries (node 7) has the lowest value (00000), and the paper by Avery (node 20) has the greatest nodal weighting ($11011_2 = 27_{10}$). The same nodal value is assigned each article in cases when the node is composed of more than one article.

NODAL WEIGHTING VALUE	FIRST AUTHOR	PUBLICATION	TYPE OF PAPER	YEAR	VOL.	PAGE
00000						
	DEVRIES H	CR AC SCI	-L	00	130	845
00001						
	BRACONNOT H	AN CHIM P	-	20	13	113
	FISCHER E	Z AN CHEM	-M	07	20	913
00010						
	BEADLE GW	P N A S	-	41	27	499
	DUVIGNEA.V	J A C S	-L	53	75	4879
	DUVIGNEA.V	J A C S	-L	53	75	4880
	MENDEL G	VERH NAT	-	65	10	3
	MULLER HJ	BR J EX B	-R	26	3	85
	PAULING L	J A C S	-L	50	72	5349
	PAULING L	P N A S	-	51	37	205
	PAULING L	P N A S	-	51	37	235
00100						
	DINTZIS HM	P N A S	-	61	47	247
	FISCHER E	BER DTSCH	-	91	24	4214
	FLEMMING W	ARC MIK A	-	79	16	302
	HERSHEY AD	J G PHYSL	-	52	36	39
	WILKINS MHF	B B ACTA	-L	53	10	192
	WILKINS MHF	NATURE	-	53	171	738
00101						
	MICHELSO.AM	J CHEM S	-	55		2632
00110						
	KOSSEL A	Z PHYSL C	-	86	10	248
	LEVENE PA	BER CHEM	-	09	42	2102
	LEVENE PA	BER CHEM	-	09	42	3247
	PALADE GE	J B B CYT	-	56	2	171
	PALADE GE	J EX MED	-	54	100	641
00111						
	HOAGLAND MB	B B ACTA	-L	57	24	215
	HOAGLAND MB	J B C	-	58	231	241
	SANGER F	BIOCHEM J	-	51	49	463
	SANGER F	BIOCHEM J	-	51	49	481
	SANGER F	BIOCHEM J	-	53	53	353
	SANGER F	BIOCHEM J	-	53	53	366
01000						
	ALLOWAY JL	J EX MED	-	32	55	91
	CONSDEN R	BIOCHEM J	-	44	38	224
	GORDON AH	BIOCHEM J	-M	43	37	R 13
	GRIFFITH F	J HYGIENE	-	28	27	113
	LEVENE PA	J B C	-	35	109	623
	STANLEY WM	SCIENCE	-L	35	81	644
01001						
	FRAENKEL.H	B B ACTA	-	57	25	87
	FRAENKEL.H	J A C S	-L	56	78	882
	FRAENKEL.H	P N A S	-	55	41	690
01010						
	EISENSTA.JM	P N A S	-	62	48	652
	JACOB F	J MOL BIO	-R	61	3	318
	KAMEYAMA T	P N A S	-	62	48	659
	KORNBERG A	B B ACTA	-L	56	21	197
	KORNBERG A	FED PROC	-M	56	15	291
	KORNBERG A	JHU MCP I	-	57	153	579
	NOVELLI GD	SCIENCE	-L	61	133	1369
	SIBATANI A	P N A S	-	62	48	471
01011						
	BAWDEN FC	NATURE	-A	36	138	1051
	BAWDEN FC	P RS BIOL	-	37	123	274
	CASPERSS.T	NATURE	-L	38	142	294
	CASPERSS.T	NATURE	-L	39	143	602
01100						
	LEVENE PA	J B C	-	29	83	793
	LEVENE PA	J B C	-	29	83	803
	MAITHAEI JH	P N A S	-	61	47	1580
	MIESCHER F	H-S M C U	-	71	460	441
	NIRENBER.MW	P N A S	-	61	47	1588
	NIRENBER.MW	P N A S	-	62	48	104
	WATSON JD	NATURE	-	53	171	737
	WATSON JD	NATURE	-	53	171	964
01101						
	HURWITZ J	B B RES C	-	60	3	15
01110						
	CHARGAFF E	C SPR H S	-M	47	12	28
10000						
	CHARGAFF E	EXPERIENT	-T	50	6	201
11000						
	GRUNBERG.M	J A C S	-L	55	77	3165
	GRUNBERG.M	SCIENCE	-	56	122	907
	OCHOA S	FED PROC	-	56	15	832
11011						
	AVERY OT	J EX MED	-	44	79	137

or self-citation pathways) was not employed when a citation line to any earlier node could be established by means used in METHOD A above. It is obvious therefore, that other citation lines could be established by investigating *all* self-citations and all other references as possible citation intermediates. The use of the more exhaustive METHOD B could not economically be applied to all the papers in the study.

Only the methods used above are displayed on the Network Charts.

NODE VALUES

Arbitrary weighting values were assigned the above connections.

CONNECTION	WEIGHT
Direct	4
Strong Indirect	2
Weak Indirect	1

Using these weights, each node can be assigned a value (expressed as a binary number) depending on the number and type of connections which enter and leave it. (In instances in which a node is composed of two or more papers, each source paper is assigned the value for the composite node.)

An example of calculating a nodal weight is given below:

Node 20(Averyet al) is cited directly by three nodes and indirectly by one node.
Node 20 directly cites two nodes and cites three other nodes indirectly.
Therefore, nine connecting lines are associated with the node.

DIRECT LINES, 5	(weight x 4)	20
INDIRECT LINES, 4		
Breakdown - STRONG INDIRECT, 3	(weight x 2)	6
WEAK INDIRECT, 1	(weight x 1	1
TOTAL Node Value		27

NODAL CITATION RELATIONSHIPS

In the following listing, relationships demonstrated by literature searching methods for each node are exactly described. The intermediate references used as pathways between nodes are listed. Referral to the Network Charts will orient the reader

Node 40 Nirenberg and Matthaei 1961-62

A. Recent end point of study therefore not cited.

B. Direct citation to Hurwitz (36).

C. Strong indirect citations.

1. Kirsch, Siekevitz, & Palade: J. Biol. Chem. 235:1419 1960 to Palade (30).

(Number in parenthesis is the nodal number.)

2. Hoagland: *Proc. Nat. Acad. Sci. U.S.* 46:1554 1960 *to* Hoagland: Proc. 4th Int. Congress Biochem. VIII. Vienna 1958 *to* Hoagland (34).
3. Hershey: *J. Gen. Physiol.* 38:145 1954 *to* Hershey: *J. Gen. Physiol.* 37:1 1953 and Hershey, Dixon and Chase: *J. Gen. Physiol.* 36:777 1952 *to* Hershey and Chase (25).

D. Weak Indirect
1. Personal communication *to* Ochoa (32).
2. Personal Communication *to* Fraenkel-Conrat (31)

Node 39 Allfrey and Mirsky 1962
A. Recent end point of study therefore *not* cited.
B. Direct Citation to Hurwitz (36), to Jacob, & Monod (35).
C. Strong Indirect Citations
1. Hoagland in "Nucleic Acids" 1960, vol. 3, pg. 360 *to* Hoagland (34).

Node 38 Novelli 1961-62
A. Recent end point of study therefore not cited.
B. Direct citation to Hurwitz (36), to Jacob & Monod (35).
C. Strong Indirect citation:
1. Ochoa: *Proc. Nat. Acad. Sci. U.S.* 47:670 1961 *to* Grunberg-Manago, Ortiz & Ochoa: *Biochim. et Biophys.* 20:269 1956 *to* Ochoa (32).

Node 37 Dintzis 1961
A. Recent end point of study therefore not cited.
B. No direct citations.
C. No strong indirect citations.
D. Weak indirect citations:
1. Steinberg et al; *Science* 124: 389 1956 *to* Sanger (24), *to* Ochoa (32).
2. Loftfield & Eigner: J. Biol. Chem. 231:925 1958 *to* Hoagland (34).
3. Loftfield, Proc. 4th Int. Congress Biochem. VIII. 222 1960 *to* Hoagland (34).
4. Borsook: Proc. 3rd Int. Congress Biochem., p. 92 1956 *to* Caspersson (17).
5. Osawa & Satake: *J. Biochem., (Tokyo)* 42:641 1956 *to* Sanger (24).

Node 36 Hurwitz 1960
A. Cited by (38) (39) (40).
B. No direct citations.
C. No strong indirect citations.
D. Weak indirect citation.
1. Weiss & Gladstone, *J. Am. Chem. Soc.* 81:4118 1959 *to* Ochoa (32).

Node 35 Jacob and Monod 1960-61
A. Cited by(38) (39).
B. No direct citations.
C. Strong indirect citations.
1. Kornberg et al: *Proc. Nat. Acad. Sci. U.S.* 45:772, 1959 *to* Kornberg (33).

Node 34 Hoagland 1957-58

A. Cited indirectly by (37) (39) (40).

B. No direct citations.

C. Strong indirect citations.

1. Caspersson: Cell Growth and Cell Function, N.Y. 1950 *to* Caspersson (17).

Node 33 Kornberg 1956-57

A. Cited by (32); cited indirectly by (35).

B. Direct citation to Ochoa (32).

C. No strong indirect citations.

Node 32 Ochoa 1955-56

A. Cited by (33); cited indirectly by (36) (37) (38) (40).

B. Direct citation to Kornberg (33) to Watson & Crick (27),to Fraenkel-Conrat (31).

C. Strong Direct citation.

1. Vischer & Chargaff: J. Biol. Chem. 176:715, 1948 *to* Chargaff (21).

D. Weak indirect citation.

1. Descriptive text reference *to* Todd (29).

Node 31 Fraenkel-Conrat 1955-57

A. Cited by (32); cited indirectly by (40).

B. No direct citations.

C. Strong indirect citations.

1. Cohen & Stanley: J. Biol. Chem. 142:863 1942 *to* Stanley & Loring: Cold Spr. Har. Sym. 6:341 1938 *and* Loring & Stanley: J. Biol. Chem. 117:733 1939 *to* Stanley (14).

2. Holden & Pirie: Biochem J. 60:46 1955 *to* Bawden & Pirie (16).

Node 30 Palade 1954-56

A. Cited indirectly by (40).

B. Direct citation to Avery et al (20)

C. No strong indirect citations.

Node 29 Todd 1955

A. Cited indirectly by (32).

B. No direct citations.

C. Strong indirect citations.

1. Michelson & Todd: J. Chem. Soc. p. 34 1954 *to* Levene (15).

2. Dekker, Michelson & Todd: J. Chem. Soc. p. 947 1953 *to* Levene (12).

Node 28 DuVigneaud 1953

A. Not cited.

B. No direct citations.

C. Strong indirect citation.

1. Popenoe & DuVigneaud J. Biol. Chem. 205:133, 1953 *to* Sanger (24).

Node 27 Watson & Crick 1953

A. Cited by (32).

B. Direct citation to Wilkins (26).

C. Strong indirect citations.

1. Pauling & Corey: *Proc. Nat. Acad. Sci.* U.S. 39:84 1953 *to* Pauling (23).
2. Zamenhof, Bawerman & Chargaff: *Biochim. et Biophys.* 9:402, 1953 *to* Chargaff (22).

Node 26 Wilkins 1953

A. Cited by (27).

B. No direct or indirect citations.

Node 25 Hershey and Chase 1952

A. Cited indirectly by (40).

B. No direct citations.

C. No strong indirect citations.

D. Weak indirect citations.

1. Anderson: *Botany Rev.* 15:464 1949 cites both Stanley & Anderson J. *Biol. Chem.* 139:325 1941 to Bawden & Pirie (16) *and* Muller H.J. *Proc. Roy. Soc. Lond.* (B) 134:1 1947 to Avery et al (20).

Node 24 Sanger 1951-53

A. Cited indirectly by (28) (37).

B. Direct citation to Martin & Synge (19).

C. No strong indirect citations.

Node 23 Pauling and Corey 1950-51

A. Cited indirectly by (27).

B. No direct or indirect citations.

Node 22 Chargaff 1950

A. Cited indirectly by (27).

B. Direct citation to Martin and Synge (19), Avery et al(20)Chargaff (21).

C. Strong indirect citation.

1. Tipson: *Adv. Carbohydrate Chem.* 1:193, 1945 to Levene & Tipson (15).

Node 21 Chargaff 1947

A. Cited by (22); indirectly cited by (32).

B. Direct citation to Avery et al (20), Mieschcr (3).

C. No strong indirect citations.

Node 20 Avery, MacLeod and McCarty 1944

A. Cited by (30) (22) (21). Cited indirectly by (25).

B. Direct Citation to Alloway (13), Griffith (11).

C. Strong indirect citations.

1. Levene & Dillon: *J. Biol. Chem.* 96:461 1933 *to* Levene (12).
2. Schultz: *Cold Spr. Har. Sym.* 9:55, 1941 *to* Caspersson & Schultz (17).

3. Stanley: Handbuch der Virusforschung 1:491 1938 *to* Stanley (14).

(This node (20) is considered the major breakthrough by Asimov. In the citation diagram it has the highest number of connecting lines and the highest node value).

Node 19 Martin and Synge 1943-44

A. Cited by (24) (22).

B. No direct or indirect citations.

Node 18 Beadle and Tatum 1941

A. Not cited.

B. No direct citations.

C. Strong indirect citation.

1. Sturtevant & Beadle: An Introduction to Genetics 1931 *to* Mendel (2).

Node 17 Caspersson and Schultz 1938-39

A. Cited indirectly by (37) (34) (20).

B. Direct citation to Bawden and Pirie (16).

C. Strong indirect citation.

1. Muller: J. *Genet.* 22:229 1930 *to* Muller (10).

Node 16 Bawden and Pirie 1936-37

A. Cited by (17); cited indirectly by (30) (25) (20).

B. Direct citation to Stanley (14).

C. No strong indirect citations.

Node 15 Levene and Tipson 1935

A. Cited indirectly by (29) (22).

B. Direct citation to Levene (12).

C. No strong indirect citations.

Node 14 Stanley 1935

A. Cited directly by (16); cited indirectly by (31) (20).

B. No direct citation to node.

C. No indirect citations.

Node 13 Alloway 1932

A. Cited by (20) .

B. Direct citation to Griffith (11).

C. No strong indirect citations.

Node 12 Levene with Mori and London 1929

A. Cited by (15); cited indirectly by (29) (20).

B. No direct citations.

C. Strong indirect citations.

1. The "work of Kossel" as described in Jones W: Nucleic Acid 2nd ed., New York, p. 136, 1920 *to* Kossel (5).

2. Levene & Jacobs; *J. Biol. Chem.* 12:411 1912 *to* Levene (9).

Node 11 Griffith 1928

A. Cited by (20) (13).

B. No direct or indirect citation to node.

Node 10 Muller 1926

A. Cited indirectly by (17)

B. No direct or indirect citations.

Node 9 Levene and Jacobs 1909

A. Cited indirectly by (12).

B. Direct citation to Fischer & Piloty (6).

C. No strong indirect citations.

Node 8 Fischer 1907

A. Not cited.

B. No direct citations.

C. No strong indirect citations.

D. Weak indirect citation.

1. Descriptive text reference *to* Braconnot (1).

Node 7 DeVries 1900

A. Not cited.

B. No direct or indirect citation (no references).

Node 6 Fischer and Piloty 1891

A. Cited by (9).

B. No direct or indirect citation*.

Node 5 Kossel 1886

A. Indirectly cited by (12).

B. Direct citation to Miescher (3).

C. No direct or indirect citation*.

Node 4 Flemming 1879

A. Not cited.

B. Direct citation to Miescher (3).

C. No strong indirect citation*.

Node 3 Miescher 1871

A. Cited by (21) (5) (4) .

B. No direct ot indirect citation. This paper represents an origional work, that is, the discovery of nucleic acid.

Node 2 Mendel 1865

A. Indirectly cited by (18).

B. No direct or indirect citation

Bateson states that Focke provides the only instance before 1900 in which Mendel was cited. He states that Mendel's work was rediscovered by DeVries (Node 7), Correns and

*Papers listed in the node bibliography were not investigated to determine if weak indirect connections existed, because of the difficulty of procuring foreign references over 70 years old.

Tschermarr in 1900. [Bateson W: Mendel's Principles of Heredity, Cambridge Univ. Press, 1909, p. 317-361; Focke: Pflanzewimschlinge, p. 109, 1881.]

Node 1 Braconnot 1820

A. Indirectly cited by (8).

B. No direct or indirect citations. (Original work, earliest node).

Non-Connective Citations to Nodal Authors

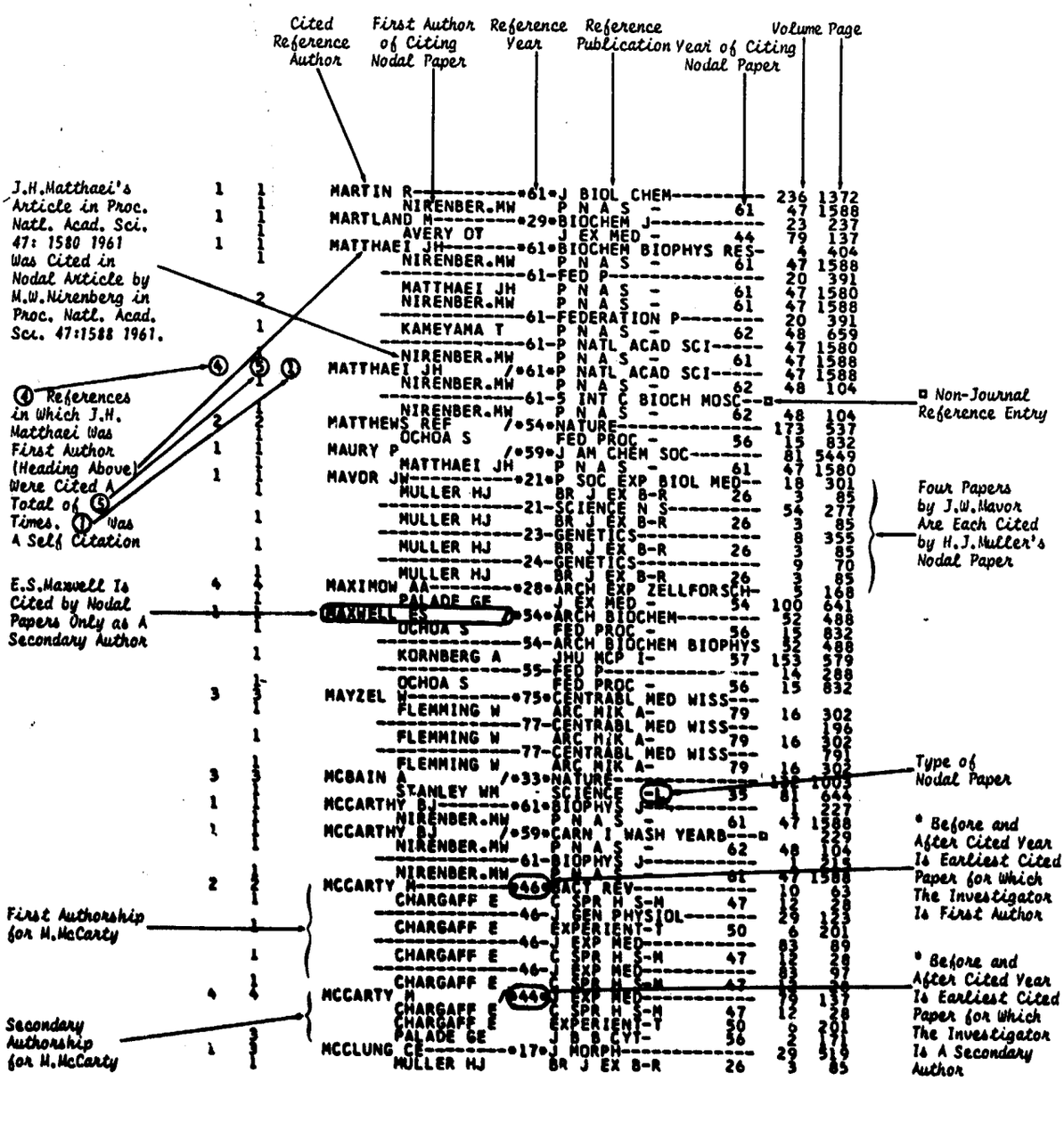
In certain nodal bibliogtaphies, citations were made to early nodal *authors*, the cited work being more recent than *paper(s)* comprising the node. However, these cited references did *not*, in these instances, provide strong indirect connections between nodes, i.e. they do not lead to the earlier *nodal papers*. Although the network chart does not indicate these cases; they are worthy of historical note.

1. (40) Nirenberg and Matthaei *cite*.
   Tissieres, Watson, Schessinger & Hollongsworth, J. *Mol. Biol.* 1:221, 1959 *which cites* Tissieres & Watson, *Nature* 182:778, 1959 which does *not* cite Watson (27).
2. Hurwitz (36) cites
   Rose, Grunberg-Manago, Corey and Ochoa, J. *Biol. Chem.* 211:737, 1954 which does *not* cite Ochoa (32).
3. (33) Kornberg cites
   Brawerman & Chargaff: J. *Amer. Chem. Soc.* 75:2020, 4113, 1953 *which cites* Vischer & Chargaff, J. *Biol. Chem.* 176:175, 1948 which does *not* cite Chargaff (21).
4. (31) Fraenkel-Conrat cites
   Watson, *Biochim. et Biophys.* 13:10, 1954 which does not cite Watson (27).
5. (17) Caspersson and Schultz cite
   Stanley, *Amer. Nat.* 62:110, 1938 which does *not* cite Stanley (14).

APPENDIX III

Citation Index Prepared from the 65 Nodal Papers

(NCI)



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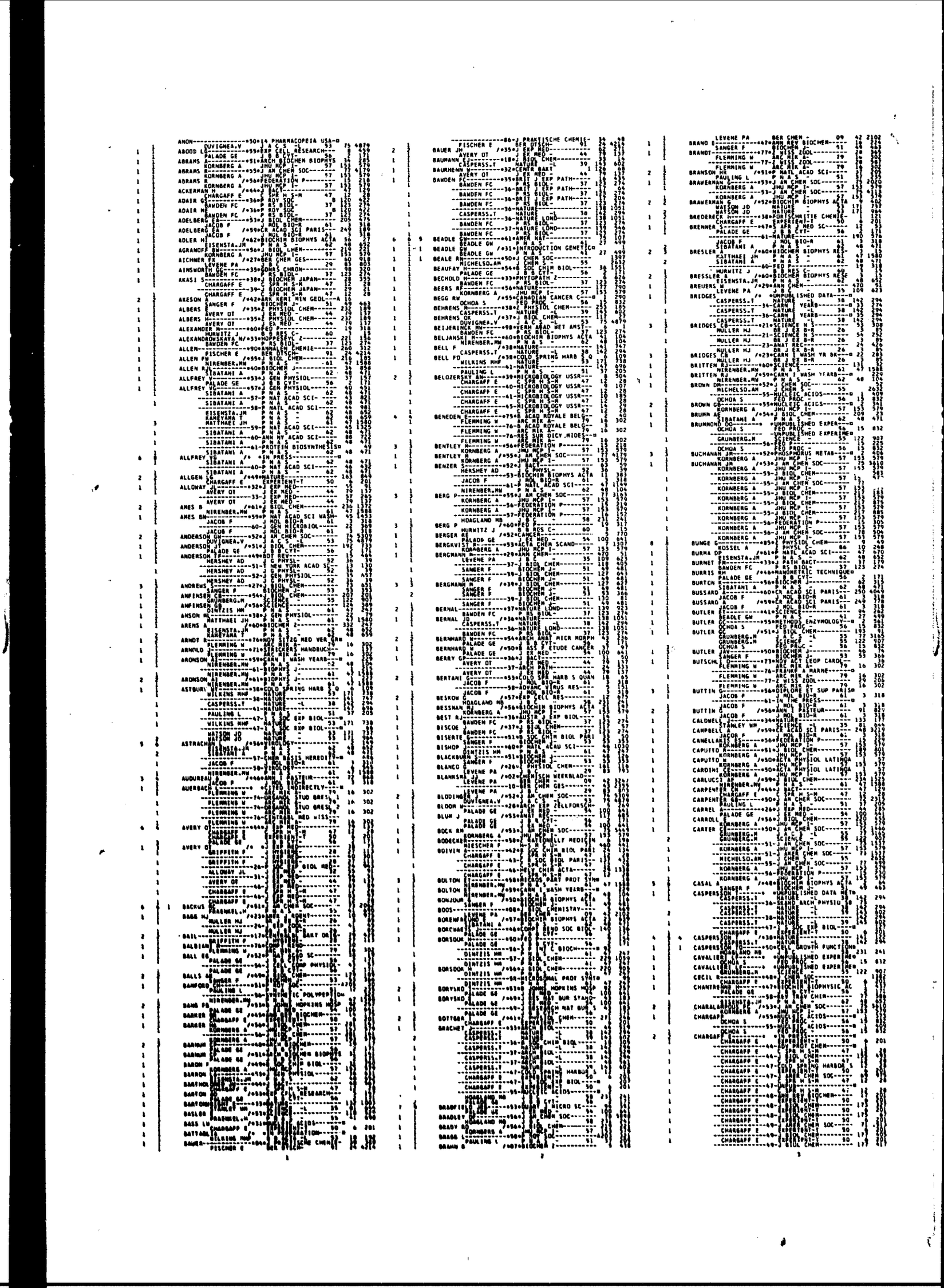
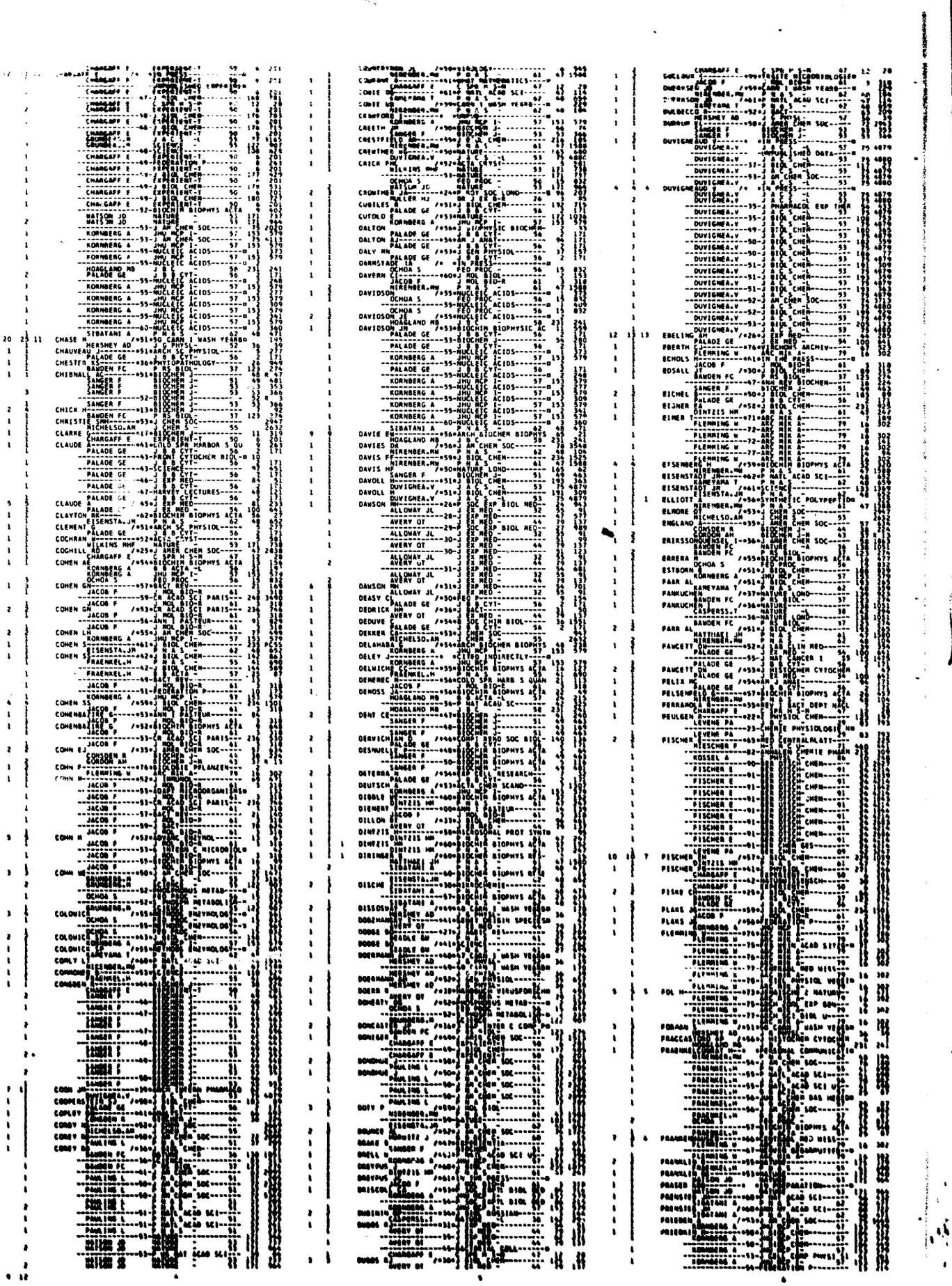
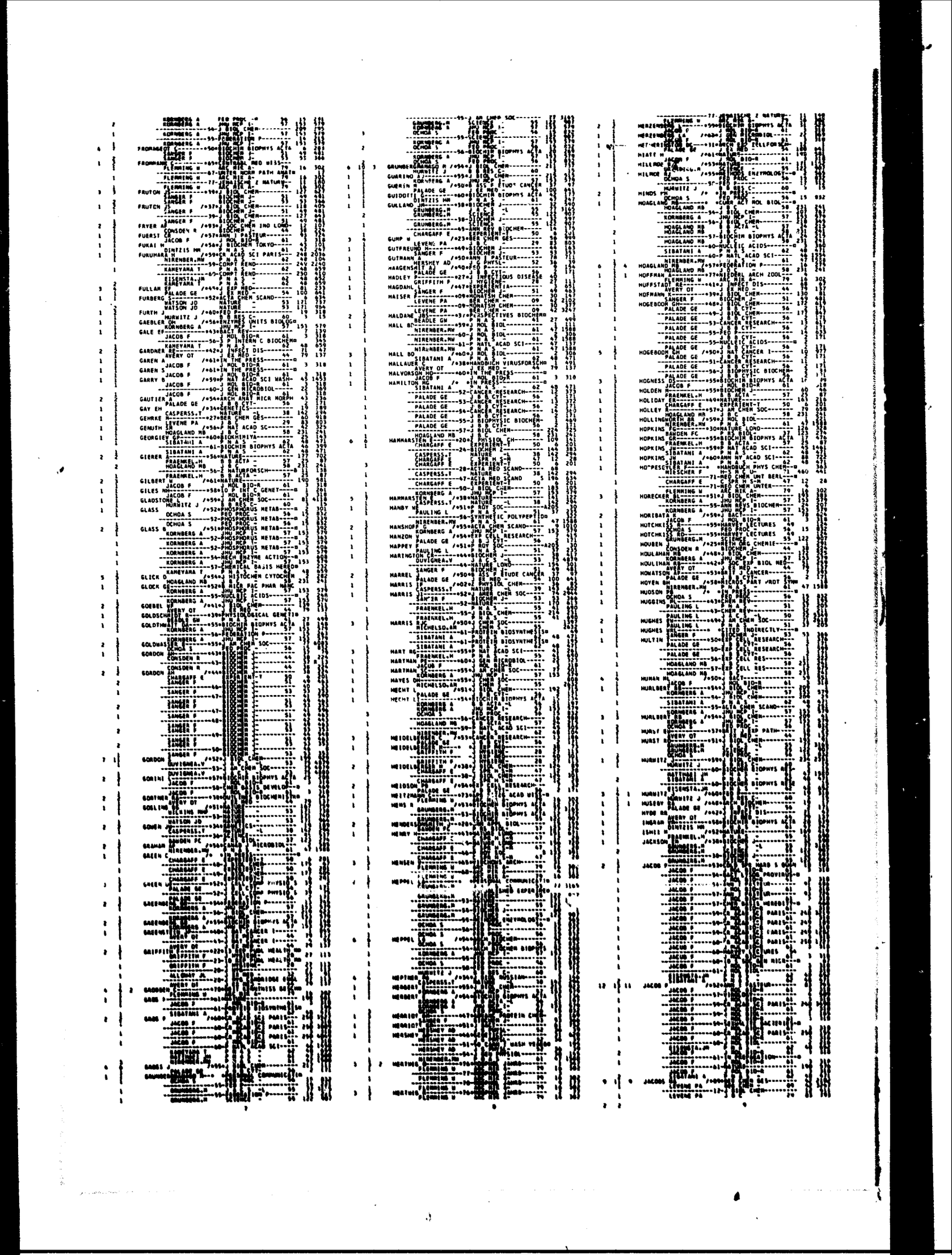
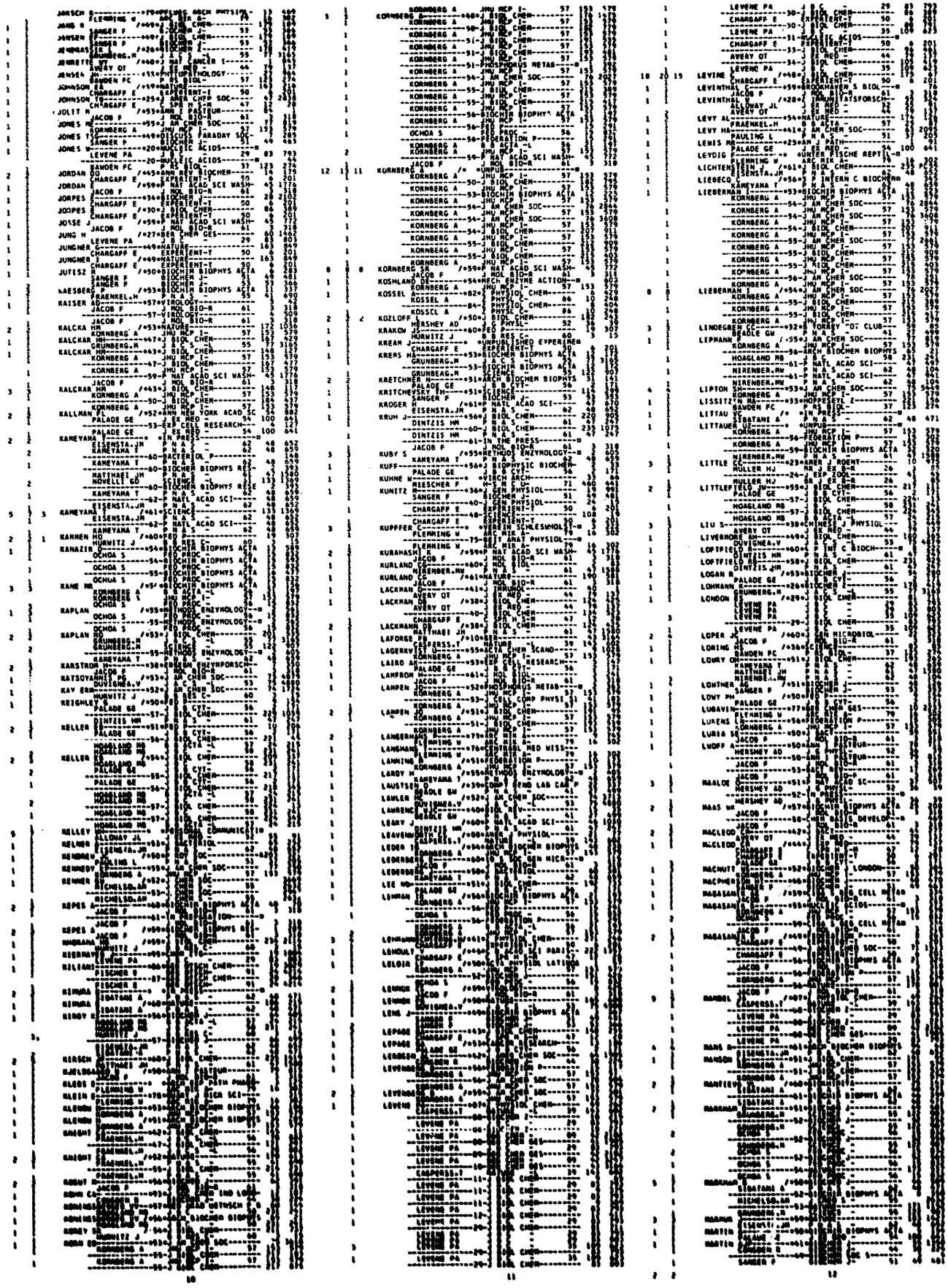
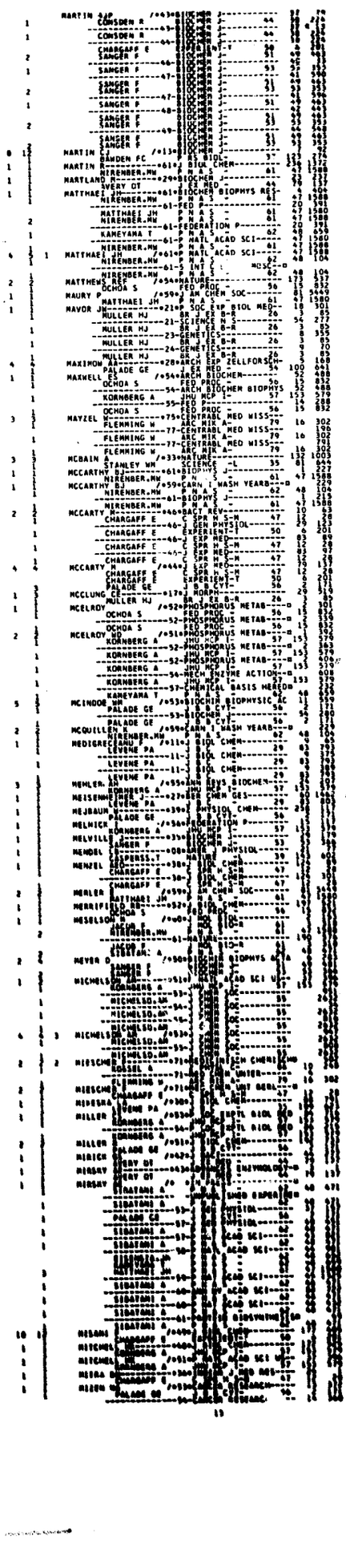
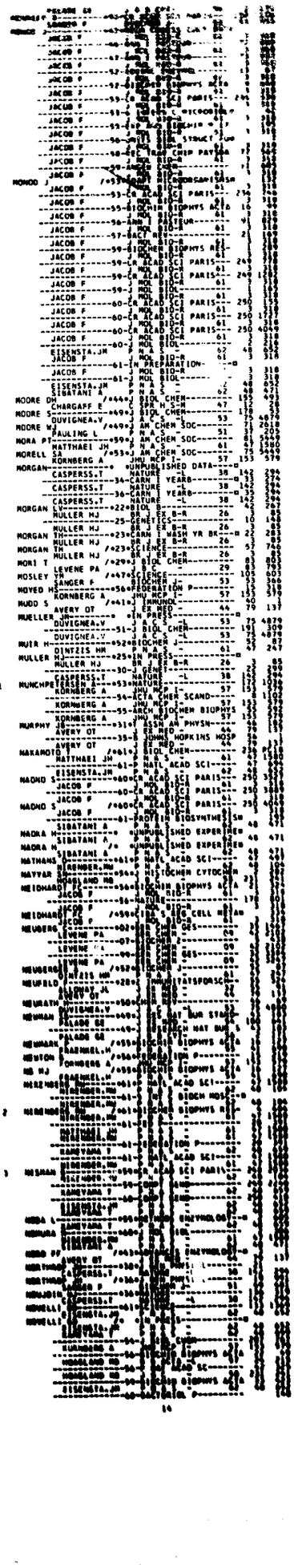


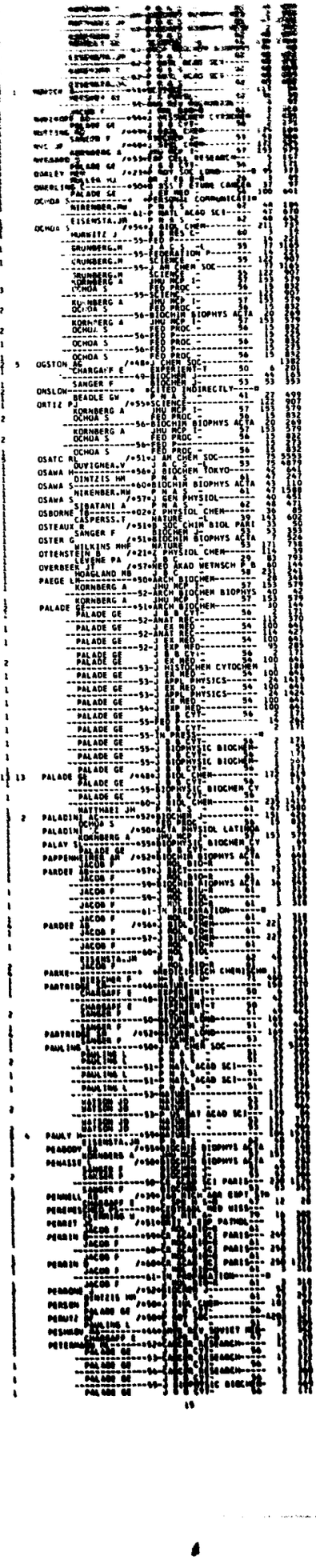


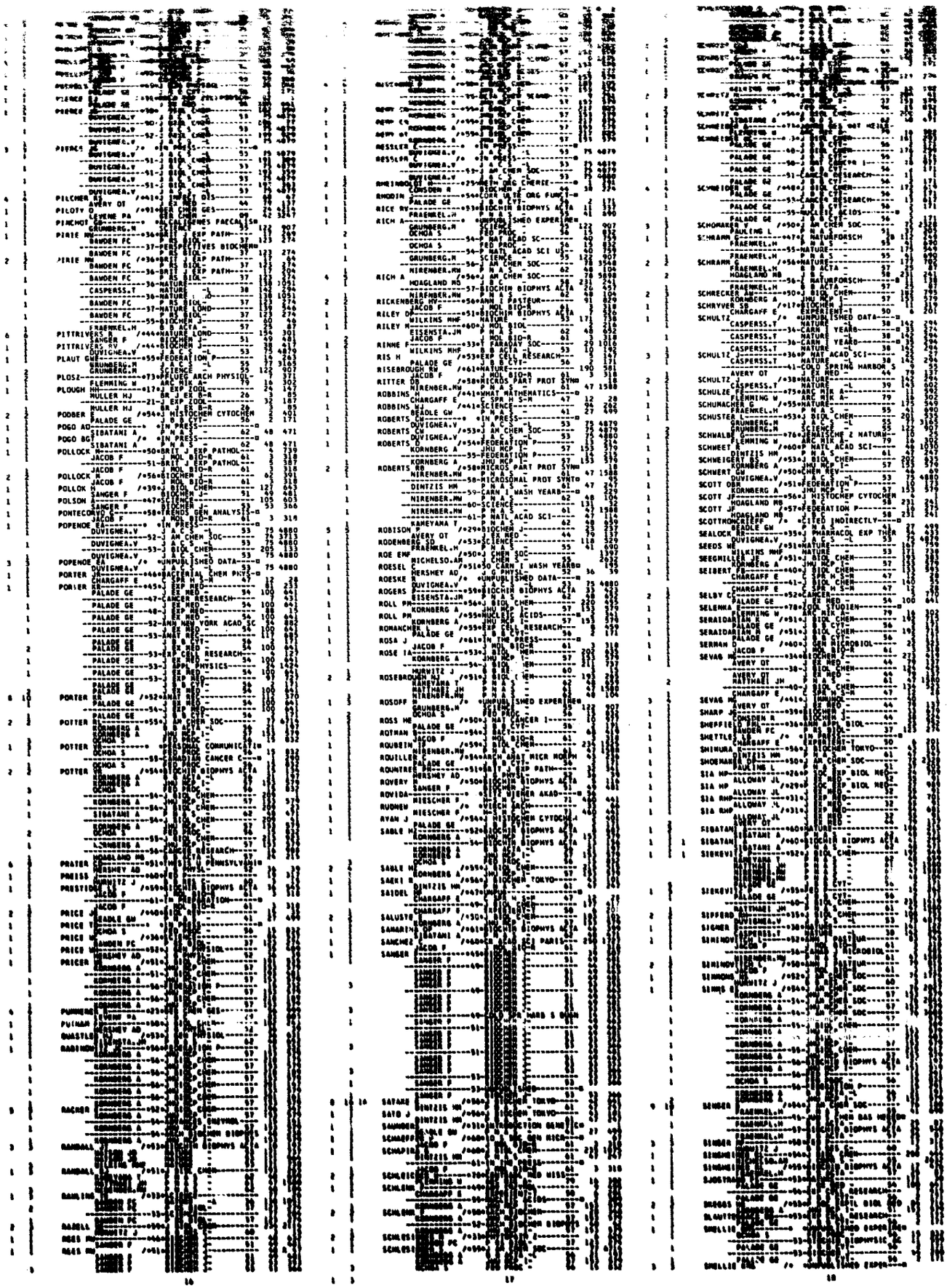


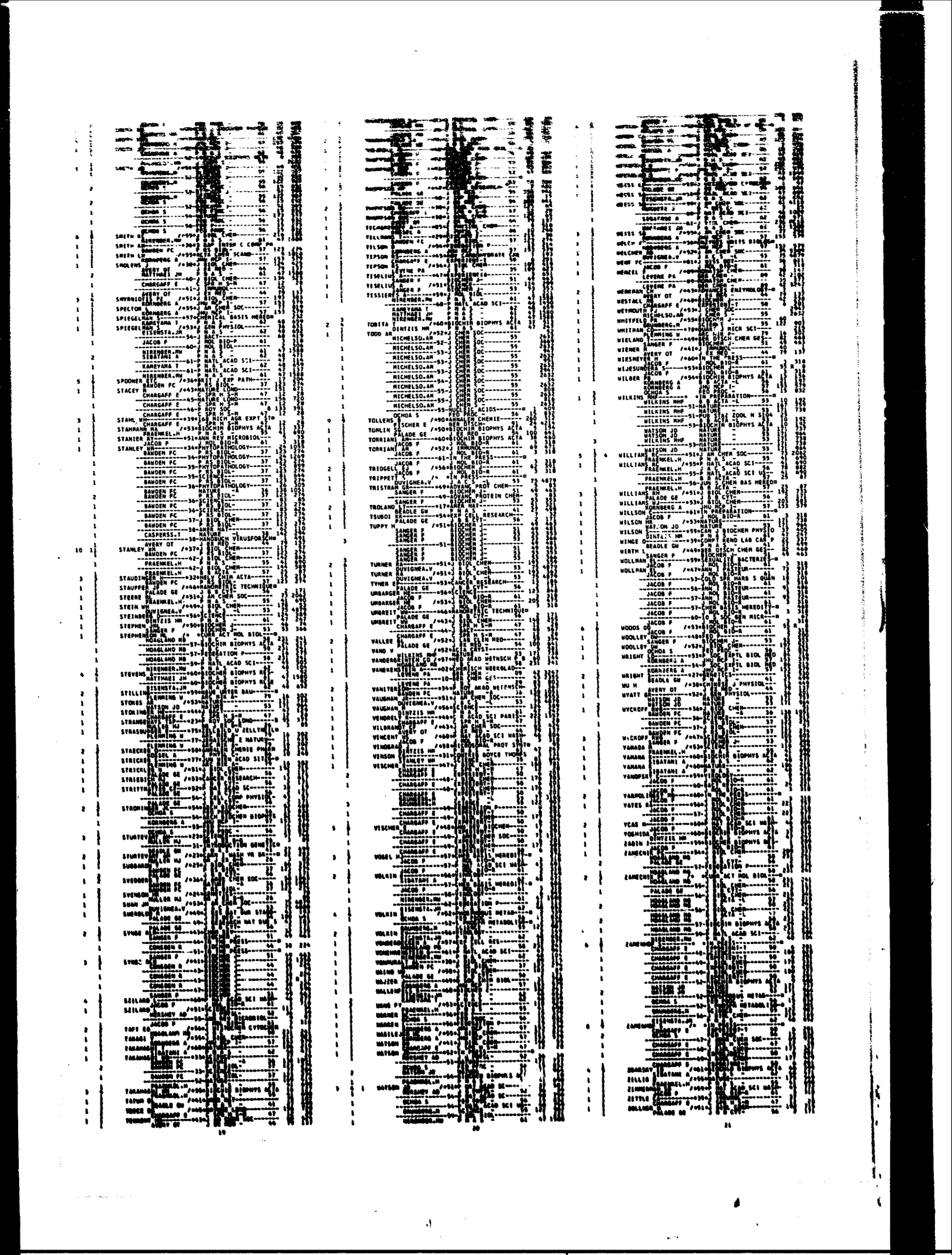












APPENDIX IV

Work Locations Specified By Nodal Articles

An article often indicates the location where, or organization under which the investigation was conducted. From the nodal papers, twenty-five locations are listed together with the number of articles for each location. Since certain nodes contain multiple articles, the actual number of nodes represented for each location is also listed. The Rockefeller Institute for Medical Research was the location where the work constituting eight nodes was conducted, and therefore is most important in the historical scheme.

INSTITUTION	NO. OF NODES INVOLVED	FIRST AUTHOR	PUBLICATION	TYPE OF PAPER	YEAR	VOL.	PAGE
•CAL I TECH							
	1	PAULING L	J A C S	-L	50	72	5349
		PAULING L	P N A S	-	51	37	205
		PAULING L	P N A S	-	51	37	235
•CARNEGIE I WASH							
	1	HERSHEY AD	J G PHYSL	-	52	36	39
•CAROLINE I							
	1	CASPERSS.T	NATURE	-L	38	142	294
		CASPERSS.T	NATURE	-L	39	143	602
•COLUMBIA U							
	1	CHARGAFF E	EXPERIENT	-T	50	6	201
•CORNELL MED COL							
	1	DUVIGNEA.V	J A C S	-L	53	75	4879
		DUVIGNEA.V	J A C S	-L	53	75	4880
•HARVARD U							
	1	HOAGLAND MB	B B ACTA	-L	57	24	215
		HOAGLAND MB	J B C	-	58	231	241
•I PASTEUR PARIS							
	1	JACOB F	J MOL BIO	-R	61	3	318
•KIEL U							
	1	FLEMMING W	ARC MIK A	-	79	16	302
•KINGS COLLEGE							
	1	WILKINS MHF	B B ACTA	-L	53	10	192
		WILKINS MHF	NATURE	-	53	171	738
•MASS I TECHN							
	1	DINTZIS HM	P N A S	-	61	47	247
•MINISTRY HEALTH							
	1	GRIFFITH F	J HYGIENE	-	28	27	113
•NAT I HEALTH							
		MATTHAEI JH	P N A S	-	61	47	1580
	1	NIRENBER.MW	P N A S	-	61	47	1588
		NIRENBER.MW	P N A S	-	62	48	104
•NYU COLLEGE MED							
		GRUNBERG.H	J A C S	-L	55	77	3165
	2	GRUNBERG.H	SCIENCE	-	55	122	907
		HURWITZ J	J B C	-	60	3	15
		OCHOA S	FED PROC	-	56	15	832
•OAKRIDGE NAT LAB							
		EISENSTA.JM	P N A S	-	62	48	652
	1	KANEYAMA T	P N A S	-	62	48	659
		NOVELLI GD	SCIENCE	-L	61	133	1369
•PHYSIOL I BERLIN							
	1	KOSSEL A	Z PHYSL C	-	86	10	248
•ROCKEF I MED RES							
		ALLOWAY JL	J EX MED	-	32	55	91
		AVERY OT	J EX MED	-	44	79	137
		LEVENE PA	BER CHEM	-	09	42	2102
		LEVENE PA	BER CHEM	-	09	42	3247
		LEVENE PA	J B C	-	29	83	793
	8	LEVENE PA	J B C	-	29	83	803
		LEVENE PA	J B C	-	35	109	623
		PALADE GE	J B B CYT	-	56	2	171
		PALADE GE	J EX MED	-	54	100	641
		SIBATANI A	P N A S	-	62	48	471
		STANLEY WM	SCIENCE	-L	35	81	644
•ROTHAMSTED STA							
	1	BAWDEN FC	NATURE	-A	36	138	1051
		BAWDEN FC	P RS BIOL	-	37	123	274
•STANFORD U							
	1	BEADLE GW	P N A S	-	41	27	499
•U BASEL							
	1	MIESCHER F	H-S M C U	-	71	460	441
•U CALIFORNIA							
		FRAENKEL.M	B B ACTA	-	57	25	87
	1	FRAENKEL.M	J A C S	-L	56	78	882
		FRAENKEL.M	P N A S	-	55	41	690
•U CAMBRIDGE							
		BAWDEN FC	NATURE	-A	36	138	1051
		BAWDEN FC	P RS BIOL	-	37	123	274
		MICHELSO.AM	J CHEM S	-	55		2632
		SANGER F	BIOCHEM J	-	51	49	463
	4	SANGER F	BIOCHEM J	-	51	49	481
		SANGER F	BIOCHEM J	-	53	53	353
		SANGER F	BIOCHEM J	-	53	53	366
		WATSON JD	NATURE	-	53	171	737
		WATSON JD	NATURE	-	53	171	964
•U TEXAS							
	1	MULLER HJ	BR J EX B	-R	26	3	85
•U WURZBURG							
	1	FISCHER E	BER DTSCH	-	91	24	4214
•WASH U SCH MED							
		KORNBERG A	B B ACTA	-L	56	21	197
	1	KORNBERG A	FED PROC	-N	56	15	291
		KORNBERG A	JHU MCP I	-	57	153	579
•WOOL IND RES ASS							
	1	CONSDEN R	BIOCHEM J	-	44	38	224

APPENDIX V

Agencies Supporting The Research

Most nodal articles, especially those of recent years, list the contributing agencies which provided funds for the investigations.

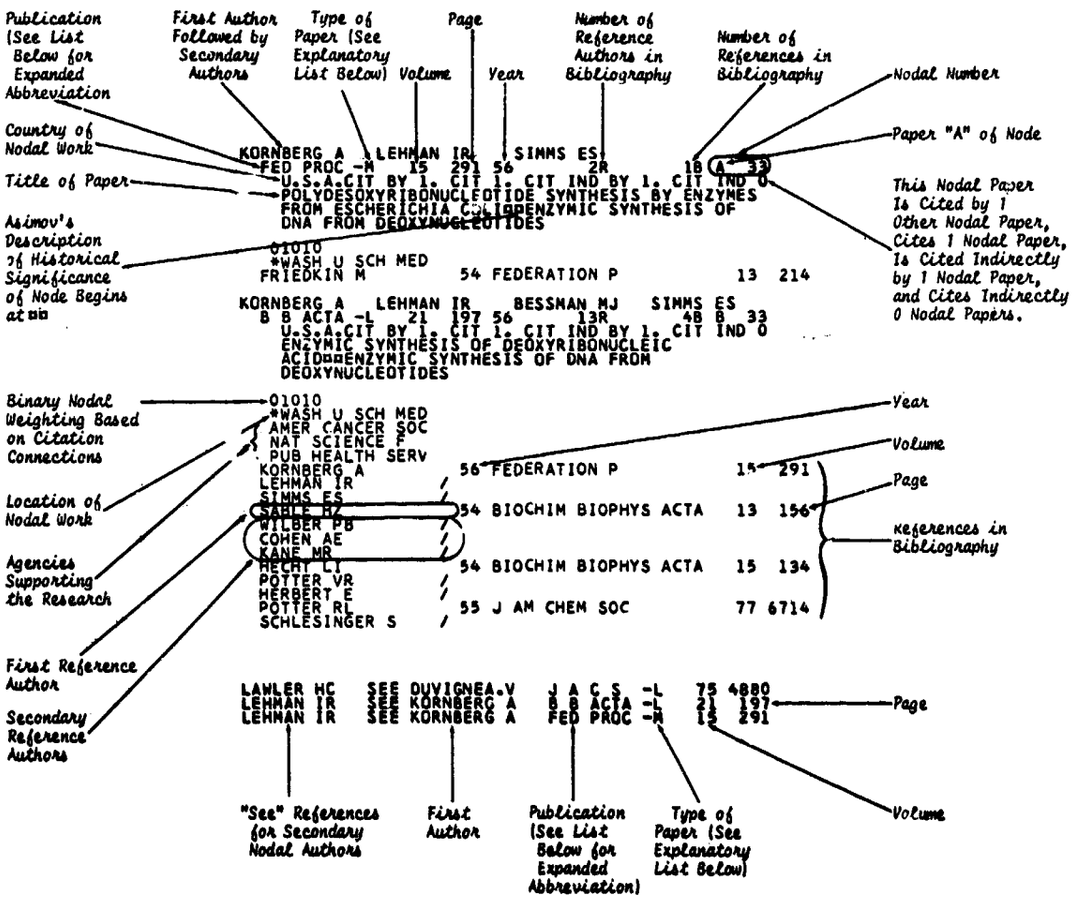
The papers in node 32 (represented by first authors Grunberg-Manago and Ochoa) received the most diverse support.

The U.S. Public Health Service provided the most extensive support since it contributed to work forming nine nodes.

AGENCIES SUPPORTING THE RESEARCH	NO. OF NODES INVOLVED	FIRST AUTHOR	PUBLICATION	TYPE OF PAPER	YEAR	VOL.	PAGE
AMER CANCER SOC							
		GRUNBERG.M	J A C S	-L	55	77	3165
		GRUNBERG.M	SCIENCE	-	55	122	907
	5	HOAGLAND MB	J B C	-	58	231	241
		KORNBERG A	B B ACTA	-L	56	21	197
		KORNBERG A	JHU MCP I	-	57	153	579
		OCHOA S	FED PROC	-	56	15	832
AMER CYAN CO							
	1	DUVIGNEA.V	J A C S	-L	53	75	4879
	1	DUVIGNEA.V	J A C S	-L	53	75	4880
ATOM ENERGY COM							
	1	HOAGLAND MB	B B ACTA	-L	57	24	215
		HOAGLAND MB	J B C	-	58	231	241
COM ENERG ATOMIQ							
	1	JACOB F	J MOL BIO	-R	61	3	318
DAZIAN F MED RES							
	1	HURWITZ J	B B RES C	-	60	3	15
GUGGENHEIM MEM F							
	1	CHARGAFF E	EXPERIENT	-T	50	6	201
JANE COFFIN FUND							
	2	HURWITZ J	B B RES C	-	60	3	15
		JACOB F	J MOL BIO	-R	61	3	318
MED RES COUN BR							
	1	SANGER F	BIOCHEM J	-	51	49	463
		SANGER F	BIOCHEM J	-	51	49	481
MICROBIOLOGICAL I							
	1	HERSHEY AD	J G PHYSL	-	52	36	39
NAT CANCER I							
	1	FRAENKEL.M	B B ACTA	-	57	25	87
		FRAENKEL.M	P N A S	-	55	41	690
NAT F INF PARALYS							
		FRAENKEL.M	B B ACTA	-	57	25	87
		FRAENKEL.M	J A C S	-L	56	78	882
	2	FRAENKEL.M	P N A S	-	55	41	690
		PAULING L	J A C S	-L	50	72	5349
		PAULING L	P N A S	-	51	37	205
		PAULING L	P N A S	-	51	37	235
NAT I ART MET DIS							
	1	GRUNBERG.M	SCIENCE	-	55	122	907
		OCHOA S	FED PROC	-	56	15	832
NAT I HEALTH							
	1	HURWITZ J	B B RES C	-	60	3	15
NAT SCIENCE F							
	1	KORNBERG A	B B ACTA	-L	56	21	197
		KORNBERG A	JHU MCP I	-	57	153	579
NATL SCIENCE F							
	1	JACOB F	J MOL BIO	-R	61	3	318
OFFICE NAVAL RES							
		GRUNBERG.M	J A C S	-L	55	77	3165
	1	GRUNBERG.M	SCIENCE	-	55	122	907
		OCHOA S	FED PROC	-	56	15	832
PUB HEALTH SERV							
		CHARGAFF E	EXPERIENT	-T	50	6	201
		FRAENKEL.M	B B ACTA	-	57	25	87
		FRAENKEL.M	P N A S	-	55	41	690
		GRUNBERG.M	J A C S	-L	55	77	3165
		GRUNBERG.M	SCIENCE	-	55	122	907
		HERSHEY AD	J G PHYSL	-	52	36	39
		HOAGLAND MB	B B ACTA	-L	57	24	215
	9	HOAGLAND MB	J B C	-	58	231	241
		HURWITZ J	B B RES C	-	60	3	15
		KORNBERG A	B B ACTA	-L	56	21	197
		KORNBERG A	JHU MCP I	-	57	153	579
		OCHOA S	FED PROC	-	56	15	832
		PAULING L	P N A S	-	51	37	205
		PAULING L	P N A S	-	51	37	235
		SIBATANI A	P N A S	-	62	48	471
ROCKEF F							
		BEADLE GW	P N A S	-	41	27	499
		GRUNBERG.M	J A C S	-L	55	77	3165
		GRUNBERG.M	SCIENCE	-	55	122	907
	3	OCHOA S	FED PROC	-	56	15	832
		PAULING L	J A C S	-L	50	72	5349
		PAULING L	P N A S	-	51	37	205
		PAULING L	P N A S	-	51	37	235

APPENDIX VI

Index of Nodal Papers



Type of Paper

- - ARTICLE
- -L LETTERS & PRELIMINARY NOTES
- -M PAPER PRESENTED AT A MEETING
- -R REVIEW ARTICLE
- -T LECTURES

Publication Abbreviations

AM NAT	AM NATURALIST		
AN CHIM P	ANN CHIM PHYS		
ARC MIK A	ARCH MIKROSKOP ANAT		
B B ACTA	BIOCHEM BIOPHYS ACTA		
B B RES C	BIOCHEM BIOPHYS RES COMMUN		
BER DTSCH	BER DEUTSCH CHEM		
BIOCHEM J	BIOCHEM J		
BR J EX B	BRIT J EXP BIOL		
C SPR H S	COLD SPRING HARBOR SYMP		
CR AC SCI	COMPT REND ACAD SCI		
EXPERIENT	EXPERIENTIA		
FED PROC	FED PROC		
H-S M C U	HOPPE-SEYLERS MED CHEM UNTERS		
J A C S	J AM CHEM SOC		
J B B CYT	J BIOPHYS BIOCHEM CYTOL		
J B C	J BIOL CHEM		
J CHEM S	J CHEM SOC		
J EX MED	J EXP MEDICINE		
J G PHYSL	J GENERAL PHYSIOL		
J HYGIENE	J HYGIENE		
J MOL BIO	J MOLEC BIOL		
JHU MCP I	JOHNS HOPKINS U + MCCOLLUM-PRATT I		
NATURE	NATURE		
P N A S	PROC NAT ACAD SCI		
P RS BIOL	PROC ROY SOC BIOL		
SCIENCE	SCIENCE		
VERH NAT	VERHANDL NATURFORSCH		
Z AN CHEM	ZEITSCH ANGEW CHEM		
Z PHYSL C	ZEITSCH PHYSIOL CHEM		

Index of Nodal Papers

ALLFREY VG SEE SIBATANI A P N A S - 48 471

ALLOWAY JL
J EX MED - 55 91 32 15R 9B 13
U.S.A.CIT BY 1. CIT 1. CIT IND BY 0. CIT IND 0
THE TRANSFORMATION IN VITRO OF R PNEUMOCOCCI INTO S FORMS OF DIFFERENT SPECIFIC TYPES BY THE USE OF FILTERED PNEUMOCOCCUS EXTRACTS□□EXTRACTS OF DEAD BACTERIA AND NOT COMPLETE CELLS WERE SUFFICIENT TO INDUCE TRANSFORMATION IN LIVING STRAINS

01000
*ROCKEF I MED RES
GRIFFITH F 28 J HYG 27 113
NEUFELD F 28 Z IMMUNITATSFORSCH 55 324
LEVINTHAL W /
DAWSON MH 30 J EXP MED 51 123
DAWSON MH 29 P SOC EXP BIOL MED 27 989
SIA HP /
SIA HP 26 P SOC EXP BIOL MED 24 709
KELLEY WH PERSONAL COMMUNICATI□
DAWSON MH 26 P SOC EXP BIOL MED 24 943
AVERY OT /
DAWSON MH 31 J EXP MED 54 681
SIA RHP /
SIA RHP 31 J EXP MED 54 701
DAWSON MH /

AVERY OT MACLEOD CM MCCARTY M
J EX MED - 79 137 44 64R 37B 20
U.S.A.CIT BY 3. CIT 2. CIT IND BY 1. CIT IND 3
STUDIES ON THE CHEMICAL NATURE OF THE SUBSTANCE INDUCING TRANSFORMATION OF PNEUMOCOCCAL TYPES - INDUCTION OF TRANSFORMATION BY A DESOXYRIBONUCLEIC ACID FRACTION ISOLATED FROM PNEUMOCOCCUS TYPE 3□□DEMONSTRATED THAT GENETIC INFORMATION COULD BE TRANSFORMED BY DNA ALONE

11011
*ROCKEF I MED RES
GRIFFITH F 28 J HYG CAMBRIDGE ENGL 27 113
NEUFELD F 28 Z IMMUNITATSFORSCH 55 324
LEVINTHAL W /
BAURHENN W 32 CENTR BAKT 1 126 68
DAWSON MH 30 J EXP MED 51 123
DAWSON MH 31 J EXP MED 54 681
SIA RHP /
ALLOWAY JL 32 J EXP MED 55 91
ALLOWAY JL 33 J EXP MED 57 265
BERRY GP 36 J BACT 31 50
DEDRICK HM /
BERRY GP 37 ARCH PATH 24 533
HURST EW 37 BRIT J EXP PATH 18 23
HOFFSTADT RE 41 J INFECT DIS 68 67
PILCHER KS /
GARDNER RE 42 J INFECT DIS 71 47
HYDE RR /
HOULIHAN RB 42 P SOC EXP BIOL MED 51 259
MACLEOD CM 42 J BACT 44 277
MIRICK GS /
DAWSON MH 28 J EXP MED 47 577
DAWSON MH 30 J EXP MED 51 99
SEVAG MG 34 BIOCHEM Z 273 419
SEVAG MG 38 J BIOL CHEM 124 425
LACKMAN DB /
SMOLENS J /
DUBOS RJ 31 J EXP MED 54 51
AVERY OT /
DUBOS RJ 35 J EXP MED 62 271
BAUER JH /
LIU S 38 CHINESE J PHYSIOL 13 449
WU H /
MARYLAND M 29 BIOCHEM J 23 237
ROBISON R /
ALBERS H 35 Z PHYSIOL CHEM 232 189
ALBERS E /
LEVENE PA 33 J BIOL CHEM 96 461
DILLON RT /
GREENSTEIN JP 40 J NAT CANCER I 1 845
JENRETTE WV /
GREENSTEIN JP 43 J NAT CANCER I 4 55
TENNENT HG 43 J AM CHEM SOC 65 424
VILBRANDT CF /
THOMPSON RHS 38 J BIOL CHEM 125 65
DUBOS RJ /
REEVES RE 41 J BIOL CHEM 139 511
GOEBEL WF /
SCHULTZ J 41 COLD SPRING HARBOR S 9 55
MIRSKY AE 43 ADVANCES ENZYMOLOGY □ 3 1
NORD FF /
WERKMAN CH /
LACKMAN D 41 J IMMUNOL 40
MUDD S /
SEVAG MG /
SMOLENS J /
WIENER M /
GORTNER RA 38 OUTLINES BIOCHEMISTR□ 547
DOBZHANSKY T 41 GENET ORIGIN SPECIES□ 47
STANLEY WM 38 HANDBUCH VIRUSFORSCH□ 1 491
DOERR R /
HALLAUER C /
MURPHY JB 31 T ASSN AM PHYSN 46 182
MURPHY JR 35 B JOHNS HOPKINS HOSP 56 1

BAWDEN FC PIRIE NW BERNAL JD FANKUCHE.I
NATURE -A 138 1051 36 9R 58 A 16
GR.BR.CIT BY 1. CIT 1. CIT IND BY 2. CIT IND 0
LIQUID CRYSTALLINE SUBSTANCES FROM VIRUS-INFECTED PLANTS□□ISOLATION OF VIRAL NUCLEIC ACID

01011
*ROTHAMSTED STA
*U CAMBRIDGE
STANLEY WM 36 PHYTOPATHOLOGY 26 305
TAKAHASHI WN 33 SCIENCE 77 26
RAWLINS TE /
VANITTERSON 34 P ROY AKAD WETENSCH 37 367
ERIKSSONQUENSEL I 36 J AMER CHEM SOC 58 1863
SVEDBERG T /
WYCKOFF RWG 36 J BIOL CHEM 51
COREY RB /

BAWDEN FC PIRIE NW
P RS BIOL- 123 274 37 G8R 44B B 16
GR.BR.CIT BY 1. CIT 1. CIT IND BY 2. CIT IND 0
THE ISOLATION AND SOME PROPERTIES OF LIQUID CRYSTALLINE SUBSTANCES FROM SOLANACEOUS PLANTS INFECTED WITH 3 STRAINS OF TOBACCO MOSAIC VIRUS□□ISOLATION OF VIRAL NUCLEIC ACID

01011
*ROTHAMSTED STA
*U CAMBRIDGE
ADAIR GS 36 P ROY SOC B 120 422
ADAIR ME /
AINSWORTH GC 35 GDNRS CHRON 98 320
BAWDEN FC 35 BRIT J EXP PATH 16 435
BAWDEN FC 36 BRIT J EXP PATH 17 64
PIRIE NW /
BAWDEN FC 37 NATURE LOND 139 546
PIRIE NW /
BAWDEN FC 36 BRIT J EXP PATH 17 204
PIRIE NW /
SPOONER ETC /
BAWDEN FC 36 NATURE LOND 138 1051
PIRIE NW /
BERNAL JD /
FANKUCHEN I /
BECHOLD H 33 PHYTOPATH Z 6 626
SCHLESINGER M /
BEIJERINCK MW 98 VERH AKAD WET AMST 6 1
BERNAL 37 NATURE LOND 139 923
FANKUCHEN /
BEST RJ 36 AUSTR J EXP BIOL 14 1
BURNET FM 33 J PATH BACT 37 179
CHESTER KS 36 PHYTOPATHOLOGY 26 949
CHICK H 13 BIOCHEM J 7 92
MARTIN CJ /
ERIKSSONQUENSEL I 36 J AMER CHEM SOC 58 1863
SVEDBERG T /
FISKE CH 25 J BIOL CHEM 66 375

SUBBAROW Y /
GOWEN JW 36 SCIENCE 84 537
PRICE WC /
HENDERSONSMITH J 28 ANN APPL BIOL 15 155
HOPKINS FG 30 NATURE LOND 126 328
JENSEN JH 33 PHYTOPATHOLOGY 23 964
JONES W 20 NUCLEIC ACIDS □ 44
LISSITZIN MA 33 HOPPESEYL Z 221 156
ALEXANDROWSKAYA N/
VONMURALT AL 30 J BIOL CHEM 89 315
EDSALL JT /
PIRIE NW 36 BRIT J EXP PATH 17 269
PIRIE NW 37 PERSPECTIVES BIOCHEM□
SCHMIDT WJ 24 BAUST TIERK POL LICH□
SHEFFIELD FM 36 ANN APPL BIOL 23 752
SMITH KM 36 3 RAP INTER C COMP P□
DONCASTER JP /
STANLEY WM 34 PHYTOPATHOLOGY 24 1055
STANLEY WM 34 PHYTOPATHOLOGY 24 1269
STANLEY WM 35 SCIENCE 81 644
STANLEY WM 35 PHYTOPATHOLOGY 25 899
STANLEY WM 36 PHYTOPATHOLOGY 26 305
STANLEY WM 36 SCIENCE 83 626
STANLEY WM 37 J BIOL CHEM 117 25
STANLEY WM 36 SCIENCE 83 85
LORING HS /
STAUDINGER H 32 HELV CHIM ACTA 15 213
TAKAHASHI WN 33 SCIENCE 77 26
RAWLINS TE /
TAKAHASHI WN 33 SCIENCE 77 284
RAWLINS TE /
TILLMANS T 29 BIOCHEM Z 215 36
PHILIPPI K /
WEBER CJ 30 J BIOL CHEM 86 216
WYCKOFF RWG 36 SCIENCE 83 513
COREY RB /
WYCKOFF RWG 37 J BIOL CHEM 117 57
BISCOE J /
STANLEY WM /

BEADLE GW TATUM EL
F N A S - 27 499 41 21R 12B 18
U.S.A.CIT BY 0. CIT 0. CIT IND BY 0. CIT IND 1
GENETIC CONTROL OF BIOCHEMICAL REACTIONS IN NEUROSPORA□□FORMULATED ONE-GENE-ONE-ENZYME THEORY

00010
*STANFORD U
ROCKEF F
TROLAND LT 17 AMER NAT 51 321
WRIGHT S 27 GENETICS 12 530
HALDANE JBS 37 PERSPECTIVES BIOCHEM□ 1
ONSLOW CITED INDIRECTLY □
SCOTTMONCKIEFF /
LAWRENCE WJC 40 BIOL REV 15 35
PRICE JR /
WINGE O 39 COMPT REND LAB CAR P 22 337
LAUSTSEN O /
GOLDSCHMIDT R 39 PHYSIOLOGICAL GENETI□ 1
BEADLE GW 41 AMER NAT 75 107
TATUM EL /
STURTEVANT AH 31 INTRODUCTION GENETIC□ 1
BEADLE GW /
SAUNDERS /
DODGE BO 27 J AGRIC RES 35 289
LINDEGREN CC 32 B TORREY BOT CLUB 59 85
BUTLER ET 41 SCIENCE 94 262
ROBBINS WJ /
DODGE BO /

BERNAL JD SEE BAWDEN FC NATURE -A 138 1051
BESSMAN MJ SEE KORNBERG A B B ACTA -L 21 169

BRACONNOT H
AN CHIM P- 13 113 20 1R 0 1
FRAN. CIT BY 0. CIT 0. CIT IND BY 1. CIT IND 0
□□ISOLATION OF GLYCINE AND LEUCINE FROM PROTEIN

00001
**
BRANSON HR SEE PAULING L P N A S -A 37 205
BRESLER A SEE HURWITZ J B B RES C- 1 15

CASPERSS.T SCHULTZ J
NATURE -L 143 602 39 16R 10B B 17
SWED. CIT BY 0. CIT 1. CIT IND BY 3. CIT IND 1
NUCLEIC ACID METABOLISM OF THE CHROMOSOMES IN RELATION TO GENE REPRODUCTION□□RNA CONCENTRATION INCREASES IN CELLS DURING PROTEIN SYNTHESIS

01011
*CAROLINE I
CASPERSSON T 36 SKAND ARCH PHYSIO 58 73
CASPERSSON T UNPUBLISHED DATA MET□
MULLER HJ 30 J GENET 22 299
SCHULTZ J 36 P NAT ACAD SCI □ 22 27
MORGAN 34 CARN I YEARB □ 33 274
BRIDGES /
SCHULTZ /
MORGAN 36 CARN I YEARB □ 35 294
BRIDGES /
SCHULTZ /
MORGAN UNPUBLISHED DATA □
BRIDGES /
SCHULTZ /
GOWEN JW 34 GENETICS 19 189
GAY EH /
DUBININ NP 34 J BIOL RUSSIAN 3 146
HEITNER HA /
BRACHET J 33 ARCH BIOL 44 519
BRACHET J 36 B SOC CHIM BIOL 18 205
BRACHET J 37 ARCH BIOL 48 519
MOUJON NJ 36 NATURE 136 319
HAMMARSTEN E 36 BIOCHEM Z 144 385
HAMMARSTEN E 38 ACTA MED SCAND 98
SIGNER R 38 NATURE 141 122
CASPERSSON T /
HAMMARSTEN E /
BAWDEN FC 36 NATURE 138 1051
PIRIE NW /
BERNAL JD /
FANKUCHEN I /

STANLEY WM 38 AMER NAT 62 110
NORTHROP JH 38 J GEN PHYSIOL 21
ASTBURY WT 38 NATURE 141 747
BELL F /

CASPERSS.T SCHULTZ J
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PENTOSE NUCLEOTIDES IN THE CYTOPLASM OF GROWING TISSUES□□RNA CONCENTRATION INCREASES IN CELLS DURING PROTEIN SYNTHESIS

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CASPERSSON T 38 NATURE 142 294
SCHULTZ J /
CASPERSSON T 36 SKAND ARCH PHYSIO 58 73
BAUMANN EJ 18 J BIOL CHEM 33 14
OSBORNE TB 02 Z PHYSIOL CHEM 36 85
HARRIS IF /
LEVENE PA 10 BER CHEM GES 43 3164
LAFORGE FB /
BEHRENS M 38 Z PHYSIOL CHEM 253 185
BRACHET J 33 ARCH BIOL 44 519
BRACHET J 37 ARCH BIOL 48 561
MENDEL LB 08 AMER J PHYSIOL 21 77
LEAVENWORTH CS /
LEVENE PA 07 Z PHYSIOL CHEM 49 262
MANDEL JA /

CHARGAFF E
C SPR H S-M 12 28 47 71R 43B 21
U.S.A.CIT BY 1. CIT 2. CIT IND BY 1. CIT IND 0
ON THE NUCLEOPROTEINS AND NUCLEIC ACIDS OF MICROORGANISMS□□DEMONSTRATED PURINES AND PYRIMIDINES PRESENT IN UNEQUAL QUANTITIES WITHIN NUCLEIC ACIDS AND THEIR RELATIVE RATIOS VARIED IN DIFFERENT NUCLEIC ACIDS

01110
AKASI S 38 J BIOCHEM JAPAN 28 355
AKASI S 39 J BIOCHEM JAPAN 29 21
AVERY OT 44 J EXP MED 79 137
MACLEOD CM /
MCCARTY M /
BARTHOLOMEW JW 44 J BACT 48 567
UMBREIT WW /
BELOZERSKY AN 39 MICROBIOLOGY USSR 8 504
BELOZERSKY AN 40 MICROBIOLOGY USSR 9 107
BELOZERSKY AN 41 MICROBIOLOGY USSR 10 185
BELOZERSKY AN 45 MICROBIOLOGY USSR 14 29
BOIVIN A 42 B SOC CHIM BIOL PARI 24 134
BOIVIN A 43 C R SOC BIOL PARIS 137 432
BOIVIN A 46 HELV CHIM ACTA 29 1338
CHARGAFF E 44 ADV PROT CHEM □ 1
CHARGAFF E 44 J BIOL CHEM 155 493
MOORE DH /
CHARGAFF E 47 UNPUB □
SAIDEL HF /
CHARGAFF E 47 J AMER CHEM SOC 69 975
ZAMENHOF S /
COURANT R 41 WHAT MATHEMATICS □
ROBBINS H /
DUBOS RJ 45 BACTERIAL CELL □
FENKAMOLA R 35 REV I BACT DEPT NACL 7 32
HAMMARSTEN E 24 BIOCHEM Z 144 383
HENRY M 43 NATURE LOND 151 671
STACEY M /
HENRY M 46 P ROY SOC B 133 391
STACEY M /
HENRY M 45 NATURE LOND 156 720
STACEY M /
TEECE EG /
HOPPESEYLER F 71 MED CHEM UNT BERL □
MIESCHER F /
JOHNSON TB 25 J AMER CHEM SOC 47 2838
COGHILL RD /
LEPAGE GA 43 J BIOL CHEM 148 251
UMBREIT WW /
MCCARTY M 46 BACT REV 10 63
MCCARTY M 46 J EXP MED 83 89
AVERY OT /
MCCARTY M 46 J EXP MED 83 97
AVERY OT /
MENZEL AEO 38 J BIOL CHEM 124 89
MEIDELBERGER M /
MENZEL AEO 38 J BIOL CHEM 124 301
MEIDELBERGER M /
MITRA BN 36 INDIAN J MED RES 24 1
PESHKOV MA 44 AMER REV SOVIET MED 1 343
PETRIK FG 46 J BACT 51 539
PORTER JR 46 BACTERIAL CHEM PHYS □
SEIBERT FB 40 J BIOL CHEM 133 593
SEIBERT FB 41 J BIOL CHEM 140 95
WATSON DW /
SEVAG MG 40 J BIOL CHEM 134 523
SMOLENS J /
LACKMAN DB /
STAHL WH 39 168 MICH AGR EXPT ST□ 3
PENNELL RB /
STOLTINGER ME 44 J BACT 47 129
ACKERMAN M /
CARPENTER CM /
THOMPSON RH 38 J BIOL CHEM 125 65
DUBOS RJ /
VENDRELY R 46 C R ACAD SCI PARIS 222 1397
LEHOULT Y /
VISCHER E 47 J BIOL CHEM 168 781
CHARGAFF E /
ZITTLE CA 39 J IMMUNOL 37 1

CHARGAFF E
EXPERIENT-T A 201 50 98R 41B 22
U.S.A.CIT BY 0. CIT 5. CIT IND BY 1. CIT IND 1
CHEMICAL SPECIFICITY OF NUCLEIC ACIDS AND MECHANISM OF THEIR ENZYMATIC DEGRADATION□□NUCLEOTIDES ARRANGED IN RANDOM ORDER WITHIN A POLYNUCLEOTIDE CHAIN

10000
*COLUMBIA U
PUB HEALTH SERV
GUGGENHEIM MEM F
HAMMARSTEN E 36 BIOCHEM Z 144 381
BRACHET J 47 C R SOC EXP BIOL □ 141 201
BRACHET J 47 COLD SPRING HARBOR S 12 10

CASPERSSON T — 47 1 S SOC EXP BIOL ¤ — 127
AVERY OT — 44 J EXP MED — 79 137
MACLEOD CM /
MCCARTY M /
LEVENE PA — 31 NUCLEIC ACIDS ¤
BASS LW /
BREDERECK H — 38 FORTSCHRITTE CHEMIE — 1 121
FISCHER FG — 42 NATURWISSENSCH — 30 377
TIPSON RS — 45 ADV CARBOHYDRATE CHE — 1 193
GULLAND JM — 45 ANN REV BIOCHEM — 14 175
BARKER GR /
JORDAN DO /
CHARGAFF E — 48 ANN REV BIOCHEM — 17 201
VISCHER E /
SCHLENK F — 49 ADV ENZYMOL — 9 455
CHARGAFF E — 47 COLD SPRING HARBOR S — 12 28
HAMMARSTEN E — 47 ACTA MED SCAND S — 196 634
JUNGNER G — 49 NATURE — 163 849
JUNGNER I /
ALLGEN LG /
CECIL R — 48 J CHEM SOC — 1382
OGSTON AG /
CONSDEN R — 44 BIOCHEM J — 38 224
GORDON AH /
MARTIN AJP /
FISCHER FG — 41 Z PHYSIOL CHEM — 271 246
BOTTGER I /
LEHMANNECHTERNA.H/
MCCARTY M — 46 J GEN PHYSIOL — 29 123
CHARGAFF E — 48 J BIOL CHEM — 173 327
ZAMENHOF S /
CHARGAFF E — 49 J BIOL CHEM — 177 417
SAIDEL HF /
ZAMENHOF S — IN PRESS ¤
SHETTLES LB /
CHARGAFF E /
CLARKE G — 17 BIOCHEM J — 11 319
SCHRYVER SB /
VISCHER E — 47 J BIOL CHEM — 168 781
CHARGAFF E /
VISCHER E — 48 J BIOL CHEM — 176 703
CHARGAFF E /
CHARGAFF E — 49 J AMER CHEM SOC — 71 1513
MAGASANIK B /
DONIGER R /
VISCHER E /
HOLIDAY ER — 49 NATURE — 163 216
JOHNSON EA /
VISCHER E — 48 J BIOL CHEM — 176 703
CHARGAFF E /
KREAM J — UNPUBLISHED EXPERIME¤
CHARGAFF E /
VISCHER E — 49 FEDERATION P — 8 263
MAGASANIK B /
CHARGAFF E /
VISCHER E — 48 J BIOL CHEM — 176 715
CHARGAFF E /
CHARGAFF E — 49 J BIOL CHEM — 177 405
VISCHER E /
DONIGER R /
GREEN C /
MISANI F /
CHARGAFF E — IN PRESS ¤
ZAMENHOF S /
GREEN C /
VISCHER E — 49 J BIOL CHEM — 177 429
ZAMENHOF S /
CHARGAFF E /
HAMMARSTEN E — 20 Z PHYSIOL CH — 109 141
LEVENE PA — 30 J BIOL CHEM — 86 389
JORPES E /
JORPES E — 34 BIOCHEM J — 28 2102
PARTRIDGE SM — 46 NATURE — 158 545
PARTRIDGE SM — 43 BIOCHEM J — 42 238
WESTALL RG /
CHARGAFF E — 48 J BIOL CHEM — 175 67
LEVINE C /
GREEN C /
VISCHER E — 49 J BIOL CHEM — 177 429
ZAMENHOF S /
CHARGAFF E /
CHARGAFF E — 49 J BIOL CHEM — 177 405
VISCHER E /
DONIGER R /
GREEN C /
MISANI F /
KUNITZ M — 40 J GEN PHYSIOL — 24 15
KUNITZ M — 48 SCIENCE — 108 19
ZAMENHOF S — 49 J BIOL CHEM — 178 531
CHARGAFF E /
ZAMENHOF S — 48 SCIENCE — 108 628
CHARGAFF E /
ZAMENHOF S — 49 J BIOL CHEM — 180 727
CHARGAFF E /

CHASE M SEE HERSHEY AD J G PHYSL- 36 39

CONSDEN R GORDON AH MARTIN AJP
BIOCHEM J- 38 224 44 19OR 108 8 19
GR-BR-CIT BY O. CIT O. CIT IND BY O. CIT IND O
QUALITATIVE ANALYSIS OF PROTEINS - A PARTITION CHROMATOGRAPHIC METHOD USING PAPER¤¤DEVELOPED PAPER CHROMATOGRAPHY AS AN ACCURATE MEANS FOR IDENTIFICATION OF AMINO ACIDS AND PURINE-PYRIMIDINE CONTENT OF NUCLEIC ACIDS

01000
*WOOL IND RES ASS
COPLEY GN — 41 ANALYST — 66 492
ENGLAND A — 35 J AMER CHEM SOC — 57 634
COHN EJ /
GORDON AH — 43 BIOCHEM J — 37 79
MARTIN AJP /
SYNGE RLM /
GORDON AH — 43 BIOCHEM J — 37 R 13
MARTIN AJP /
SYNGE RLM /
KOHN CA — 93 J SOC CHEM IND LOND — 12 107
FRYER AF /
LEROSEN AL — 42 J AMER CHEM SOC — 64 1905
MARTIN AJP — 41 BIOCHEM J — 35 1358
SYNGE RLM /
RHEINBOLDT H — 29 METH ORG CHEMIE ¤ — 1 291
HOUBEN J /
SHARP JG — 39 BIOCHEM J — 33 679
SYNGE RLM — 44 IN THE PRESS ¤

COREY RB SEE PAULING L J A C S -L 72 5349
COREY RB SEE PAULING L P N A S - 37 205
COREY RB SEE PAULING L P N A S - 37 235
CRICK FHC SEE WATSON JD NATURE - 171 737
CRICK FHC SEE WATSON JD NATURE - 171 964
DEKLOET SR SEE SIBATANI A P N A S - 48 471

DEVRIES H
CR AC SCI-L 130 845 00 1R B 7
METH. CIT BY O. CIT O. CIT IND BY O. CIT IND O
SUR LA LOI DE DISJONCTION DES HYBRIDES¤¤CONCEPT OF MUTATION

00000
••

DINTZIS HM
P N A S - 47 247 61 40R 178 37
U.S.A.CIT BY O. CIT O. CIT IND BY O. CIT IND 4
ASSEMBLY OF THE PEPTIDE CHAINS OF HEMOGLOBIN¤¤ASSEMBLED HEMOGLOBIN FROM AMINO ACIDS. DEMONSTRATED THAT TRIPLET SEQUENCE ON TRANSFER RNA DOES NOT OVERLAP

00100
*MASS I TECHN
STEINBERG D — 56 SCIENCE — 124 389
VAUGHAN M /
ANFINSEN GB /
LOFTFIELD R — 60 4 P INT C BIOCH ¤ — 8 222
BORSOOK H — 56 3 P INT C BIOCH ¤ — 92
DIBBLE WE — 60 BIOCHIM BIOPHYS ACTA — 37 152
DINTZIS HM /
KRUH J — 56 J BIOL CHEM — 220 905
BORSOOK H /
BORSOOK H — 57 J BIOL CHEM — 229 1059
FISCHER EH /
KEIGHLEY G /
INGRAM VM — 58 BIOCHIM BIOPHYS ACTA — 28 539
DINTZIS H — 58 MICROSOMAL PROT SYNT¤ — 95
BORSOOK H /
VINOGRAD J /
ROBERTS RB /
WILSON S — 59 CAN J BIOCHEM PHYSIO — 37 405
SMITH OB /
GUIDOTTI G — 60 BIOCHIM BIOPHYS ACTA — 42 177
OSAWA H — 56 J BIOCHEM TOKYO — 42 641
SATAKE K /
BISHOP J — 60 P NATL ACAD SCI — 46 1030
LEAKY J /
SCHWEET R /
YOSHIDA A — 60 BIOCHIM BIOPHYS ACTA — 37 513
TOBITA T /
SHIMURA K — 56 J BIOCHEM TOKYO — 43 101
FUKAI H /
SATO J /
SAEKI R /
MUIR H — 52 BIOCHEM J — 52 87
NEUBERGER A /
PERRONE J /
KRUH J — 60 J BIOL CHEM — 235 1075
DREYFUS J /
SCHAPIRA G /
LOFTFIELD RB — 58 J BIOL CHEM — 231 925
EIGNER EA /

DIPPEL AL SEE MULLER HJ BR J EX B-R 3 85
DIRINGER R SEE HURWITZ J B B RES C- 3 15

DUVIGNEA.V RESSLER C SWAN JM ROBERTS CW
KATSOYAN.PG GORDON S
J A C S -L 79 4879 53 49R 208 A 28
U.S.A.CIT BY O. CIT O. CIT IND BY O. CIT IND I
THE SYNTHESIS OF AN OCTAPEPTIDE AMIDE WITH THE HORMONAL ACTIVITY OF OXYTOCIN¤¤DETERMINATION OF THE AMINO ACID SEQUENCE OF VASOPRESSIN AND OXYTOCIN ALSO THEIR RESYNTHESIS

00010
*CORNELL MED COL
AMER CYAN CO
LIVERMORE AM — 49 J BIOL CHEM — 180 365
DUVIGNEAUD V /
PIERCE JG — 50 J BIOL CHEM — 182 359
DUVIGNEAUD V /
PIERCE JG — 50 J BIOL CHEM — 186 77
DUVIGNEAUD V /
PIERCE JG — 52 J BIOL CHEM — 199 929
GORDON S /
DUVIGNEAUD V /
RESSLER C — IN PRESS ¤
TRIPPETT S /
DUVIGNEAUD V /
MUELLER JM — 51 J BIOL CHEM — 191 309
PIERCE JG /
DAVOLL M /
DUVIGNEAUD V /
TURNER RA — 51 J BIOL CHEM — 193 359
PIERCE JG /
DUVIGNEAUD V /
DAVOLL M — 51 J BIOL CHEM — 193 363
TURNER RA /
PIERCE JG /
DUVIGNEAUD V /
MUELLER JM — IN PRESS ¤
PIERCE JG /
DUVIGNEAUD V /
DUVIGNEAUD V — IN PRESS ¤
RESSLER C /
TRIPPETT S /
SEALOCK RR — 35 J PHARMACOL EXP THER — 54 433
DUVIGNEAUD V /
STIFFER MH — 35 J BIOL CHEM — 108 753
DUVIGNEAUD V /
VAUGHAN JR — 51 J AM CHEM SOC — 73 5553
OSATO RL /
DUVIGNEAUD V /
BEHRENS OK — 37 J BIOL CHEM — 117 27
ANDERSON GW — 52 J AM CHEM SOC — 74 5309
BLODINGER J /
WELCHER AD /
HARRINGTON CR — 44 BIOCHEM J — 38 417
PITTMIVERS RV /
ROBERTS CW — IN PRESS ¤
DUVIGNEAUD V /
COON JM — 39 ARCH INTERN PHARMACO — 62 79

```
                    50 14 PHARMACOPEIA USA ¤
MOORE S             49 J BIOL CHEM                  178   53
STEIN WH          /

DUVIGNEA,V   LAWLER HC    POPENOE EA
  J A C S   -L    75 4880 53          21R          78 B  28
    U.S.A.CIT BY 0. CIT 0. CIT IND BY 0. CIT IND 1
    ENZYMATIC CLEAVAGE OF GLYCINAMIDE FROM
    VASOPRESSIN AND A PROPOSED STRUCTURE FOR THIS
    PRESSOR-ANTIDIURETIC HORMONE OF THE POSTERIOR
    PITUITARY¤¤DETERMINATION OF THE AMINO ACID
    SEQUENCE OF VASOPRESSIN AND OXYTOCIN ALSO
    THEIR RESYNTHESIS

   00010
   *CORNELL MED COL
   AMER CYAN CO
POPENOE EA                IN PRESS              ¤
DUVIGNEAUD V      /
POPENOE EA          53 J BIOL CHEM                205   133
DUVIGNEAUD V      /
CREWTHER WG         50 NATURE                     165   680
LENNOX FG         /
NEURATH H           50 CHEM REV                    46    69
SCHWERT GW        /
POPENOE EA          52 J AM CHEM SOC               74  3713
LAWLER HC         /
DUVIGNEAUD V      /
DUVIGNEAUD V              UNPUBLISHED DATA      ¤
POPENOE EA        /
ROESKE R          /
DUVIGNEAUD V        53 J AM CHEM SOC              75  4879
RESSLER C         /
SWAN JM           /
ROBERTS CW        /
KATSOYANNIS PG    /
GORDON S          /

EISENSTA,JM  KAMEYAMA T   NOVELLI GD
  P N A S   -    48  652 62          51R          25B B  38
    U.S.A.CIT BY 0. CIT 2. CIT IND BY 0. CIT IND 1
    A REQUIREMENT FOR GENE-SPECIFIC
    DEOXYRIBONUCLEIC ACID FOR THE CELL-FREE
    SYNTHESIS OF BETA-GALACTOSIDASE¤¤MANUFACTURED
    MESSENGER RNA FROM CELL FRAGMENTS AND USED IT
    AS A MODEL IN THE FORMATION OF BETA-
    GALACTOSIDASE

   01010
   *OAKRIDGE NAT LAB
KAMEYAMA T                62 P NATL ACAD SCI            48   659
NOVELLI GD        /
NOVELLI GD                61 SCIENCE                   133  1369
EISENSTADT JM     /
KAMEYAMA T        /
WALLENFELS K              60 BIOCHEM Z                 332   247
ARENS A           /
COHEN S                   61 J BIOL CHEM               235  PC55
LICHTENSTEIN J    /
ZAMENHOF S                56 J BIOL CHEM               219   165
KIRBY KS                  57 BIOCHEM J                  66   495
MARMUR J                  59 NATURE                    183  1427
DOTY P            /
KAMEYAMA T                IN PRESS              ¤
NOVELLI GD        /
MANS R                    61 ARCH BIOCHEM BIOPHYS       94    48
NOVELLI GD        /
ALLFREY VG                58 P NATL ACAD SCI            44   981
MIRSKY AE         /
KELNER A                  53 J BACTERIOL                65   252
NISMAN B                  60 COMPT REND                250   410
FUKUHARA H        /
BARRON LA                 53 J GEN PHYSIOL              36   631
SPIEGELMAN S      /
QUASTLER HJ       /
CHANTRENNE H              58 REV TRAV CHIM              77   586
CLAYTON RK                62 BIOCHIM BIOPHYS ACTA       56    27
ADLER HI          /
PAULY H                   59 NATURE                    184  1570
VOLKIN EV                 56 VIROLOGY                    2   149
ASTRACHAN L       /
VOLKIN E                  62 FEDERATION P               21   112
MURWITZ J                 60 BIOCHEM BIOPHYS RESE        3    15
BRESSLER A        /
DIRINGER R        /
WEISS SA                  61 P NATL ACAD SCI            47   694
NAKAMOTO T        /
STEVENS A                 60 BIOCHEM BIOPHYS RESE        3    92
OCHOA S                   61 P NATL ACAD SCI            47   670
BURMA DP          /
KROGER H          /
WEILL JD          /
ROGERS P                  59 BIOCHIM BIOPHYS ACTA       33   423
NOVELLI GD        /
JACOB F                   61 J MOL BIOL                  3   318
MONOD J           /
RILEY M                   60 J MOL BIOL                  2   216
PARDEE AB         /
JACOB F           /
MONOD J           /

EISENSTA,JM SEE NOVELLI GD   SCIENCE  -L  133 1369
FANKUCHE,I  SEE BAWDEN FC    NATURE   -A  156 1051

FISCHER E    PILOTY O
  BER DTSCH-    24 4214 91          14R          12B  6
    GERM. CIT BY 1. CIT 0. CIT IND BY 0. CIT IND 0
    UEBER EINE NEUE PENTONSAEURE UND DIE ZWEITE
    INAKTIVE TETROXYGLUTARSAEURE¤¤IDENTITY AND
    SYNTHESIS OF RIBOSE

   00100
   *U WURZBURG
FISCHER E                 91 BER DTSCH CHEM             24  1839
FISCHER E                 91 BER DTSCH CHEM             24  2683
FISCHER E                 91 BER DTSCH CHEM             24  2844
FISCHER E                 91 BER DTSCH CHEM             24  2686
FISCHER E                 91 BER DTSCH CHEM             24  1845
FISCHER E                 90 BER DTSCH CHEM             23  2621
BAUER                     84 J PRAKT CHEM               30   380
BAUER                     86 J PRAKT CHEM               34    48
KILIANI                   86 BER DTSCH CHEM             19  3029
KILIANI                   87 BER DTSCH CHEM             20   340
ALLEN                     90 ANNALEN CHEMIE            260   312
TOLLENS B         /
FISCHER E                 91 BER DTSCH CHEM             24  1843

FISCHER E
  Z AN CHEM-M   20  913 07          1R           B    8
    GERM. CIT BY 0. CIT 0. CIT IND BY 0. CIT IND 1
    PROTEINE UND POLYPEPTIDE¤¤DETERMINATION OF
    POLYPEPTIDE AMINO ACID LINKAGE OF PROTEINS

   00001
   **
FLEMMING W
  ARC MIK A-    16  302 79          71R          69B    4
    GERM. CIT BY 0. CIT 1. CIT IND BY 0. CIT IND 0
    BEITRAGE ZUR KENNTNISS DER ZELLE UND IHRER
    LEBENSERSCHEINUNGEN¤¤BASIC STUDIES OF
    CHROMOSOME REDUPLICATION DURING MITOSIS

   00100
   *KIEL U
ARNDT R                   76 NOV SITZG MED VER GR¤
ARNOLD J                  71 STRICKERS HANDBUCH                137
AUERBACH L                74 ORGANOL STUD BRESL 1
AUERBACH L                74 ORGANOL STUD BRESL 2
AUERBACH L                76 CENTRABL MED WISS
AUERBACH L                CITED INDIRECTLY      ¤
COHN F                    76 BIOLOGIE PFLANZEN           2
BALBIANI M                76 COMPT REND                 30
BENEDEN E                 75 B ACAD ROYALE BELG          2    40
BENEDEN E                 76 B ACAD ROYALE BELG          3
BRANDT                    77 Z WISS ZOOL                28   365
BENEDEN E                 76 RES SUR DICYEMIDES  ¤
BRANDT                    77 Z WISS ZOOL                28   587
BUTSCHLI O                73 NOV ACT LEOP CAROL                36
BUTSCHLI O                76 FRANKF A MARNE      ¤
BUTSCHLI O                77 Z WISS ZOOL                29   206
EBERTH CJ                 76 VIRCHOWS ARCHIV            67   523
EIMER T                   71 ARC MIK A                   7   189
EIMER T                   72 ARC MIK A                   8   141
EIMER T                   72 ARC MIK A                   8
EIMER T                   77 ARC MIK A                  14    94
FLEMMING W                74 ARC MIK A                  10   286
FLEMMING W                75 FEB WEIN ACAD SITZG ¤      71     3
FLEMMING W                76 ARC MIK A                  13   693
FLEMMING W                77 CENTRABL MED WISS
FLEMMING W                78 1 KIEL PHYSIOL VEREI¤
FOL H                     73 JENAISCHE Z NATURW          7   471
FOL H                     75 ARCH ZOOL EXP GEN           4
FOL H                     77 ARCH SCI BIBL U
FROMMANN C                65 CENTRABL MED WISS
FROMMANN C                67 UNTER NORM PATH ANAT¤              17
FROMMANN C                77 JENAISCHE Z NATURW         11   180
FRANKENHAUSER             66 CENTRABL MED WISS
FRANKENHAUSER             67 NERVEN GEBARMUTTER  ¤
GROBBEN C                 78 BEIT KENNTNISS GESCH¤
HEITZMANN C               73 APR SITZG ACAD WISS ¤
HENSEN V                  65 VIRCHOWS ARCH              31
HENSEN V                  68 ARC MIK A                   4   111
HERTWIG O                 76 MORPHOL JAHRB               1   347
HERTWIG O                 77 MORPHOL JAHRB               3
HERTWIG O                 78 MORPHOL JAHRB               4   177
HERTWIG R                 77 JENAISCHE Z NATURW         11   148
HERTWIG R                 76 MORPHOL JAHRB               2    77
HOFFMAN A                 77 NIEDERL ARCH ZOOL           4
HOPPESEYLER F             71 MED CHEM UNTER              4
JAKSCH R                  79 PFLUEG ARCH PHYSIOL        13   469
KLEBS E                   ARCH EXP PATH PHARM            3   125
KLEIN E                   78 QUART J MICR SCI                  315
KUPFFER C                 VEREIN SCHLESWHOLST ¤          3   222
KUPFFER C                 75 BEIT ANAT PHYSIOL   ¤
LANGERHANS P              73 ARC MIK A                   9   745
LANGHANS T                76 CENTRABL MED WISS
LEYDIG F                  UNTER FISCHE REPTIL ¤
LUBAVIN                   77 BER CHEM GES               10  2237
MAYZEL W                  75 CENTRABL MED WISS
MAYZEL W                  77 CENTRABL MED WISS                 196
MAYZEL W                  77 CENTRABL MED WISS                 791
MIESCHER F                71 MED CHEM UNTER              4
PEREMESCHKO PS            78 CENTRABL MED WISS
PLOSZ                     73 PFLUEG ARCH PHYSIOL         7   371
SCHLEICHER W              78 CENTRABL MED WISS
SCHNEIDER A               73 JAHRB GES NAT HEILK
SCHULZE FE                75 ARC MIK A                  11   592
SCHWALBE G                76 JENAISCHE Z NATURW         10    25
SELENKA E                 78 ZOOL STUDIEN        ¤
STILLING                  59 NEUE UNTER BAU      ¤
STRASBURGER E             75 ZELLBILD U ZELLTHEIL¤
STRASBURGER E             JENAISCHE Z NATURW            11   435
STRICKER S                77 JUN WIEN ACAD SITZG ¤
WHITMAN CO                78 QUART J MICR SCI                  215

FRAENKEL,M   WILLIAMS RC
  B BCTA -      25        87 57          20R          10B C  31
    U.S.A.CIT BY 1. CIT 0. CIT IND BY 1. CIT IND 2
    INFECTIVITY OF VIRAL NUCLEIC ACID¤¤ISOLATED
    VIRAL NUCLEIC ACID DEMONSTRATED SOME
    INFECTIVITY

   01001
   *U CALIFORNIA
   NAT F INF PARALYS
   NAT CANCER I
   PUB HEALTH SERV
FRAENKELCONRAT H          55 P NATL ACAD SCI US         41   690
WILLIAMS RC       /
FRAENKELCONRAT H          56 J AM CHEM SOC              78   882
GIERER A                  56 NATURE                    177   702
SCHRAMM G         /
GIERER A                  56 Z NATURFORSCH           B 11   138
SCHRAMM G         /
HOLDEN M                  55 BIOCHEM J                  60    46
PIRIE NW          /
LEVY AL                   54 NATURE                    174   126
FRAENKELCONRAT H          56 JUN S CHEM BAS HERED¤
SINGER B          /
WILLIAMS RC       /
FRAENKELCONRAT H          57 BIOCHIM BIOPHYS ACTA       24   540
SINGER B          /
COHEN SS                  42 J BIOL CHEM               144   589
STANLEY WM        /
HOPKINS GR                55 BIOCHIM BIOPHYS ACTA       17   476
SINSHEIMER RL     /

FRAENKEL,M
  J A C S   -L    78  882 56          3R           2B B  31
    U.S.A.CIT BY 1. CIT 0. CIT IND BY 1. CIT IND 2
    THE ROLE OF THE NUCLEIC ACID IN THE
    RECONSTITUTION OF ACTIVE TOBACCO MOSAIC
    VIRUS¤¤ISOLATED VIRAL NUCLEIC ACID
    DEMONSTRATED SOME INFECTIVITY
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01001
*U CALIFORNIA
NAT F INF PARALYS
FRAENKELCONRAT H / 55 P NATL ACAD SCI 41 690
WILLIAMS RC /
KNIGHT CA 47 J BIOL CHEM 171 297
KNIGHT CA 42 J BIOL CHEM 145 11

FRAENKEL.H WILLIAMS RC
P N A S - 41 690 55 33R 14B A 31
U.S.A.CIT BY 1. CIT 0. CIT IND BY 1. CIT IND 2
RECONSTITUTION OF ACTIVE TOBACCO MOSAIC VIRUS FROM ITS INACTIVE PROTEIN AND NUCLEIC ACID COMPONENTS¤¤VIRAL NUCLEIC ACID AND VIRAL PROTEIN COAT RECOMBINED PRODUCING INFECTIVE COMPLETE VIRUS

01001
*U CALIFORNIA
NAT F INF PARALYS
NAT CANCER I
PUB HEALTH SERV
HARRIS JI 52 NATURE 170 613
KNIGHT CA /
HARRIS JI 55 J BIOL CHEM 214 231
KNIGHT CA /
SCHRAMM G 47 Z NATURFORSCH 2B 112 249
WATSON JD 54 BIOCHIM BIOPHYS ACTA 13 10
FRANKLIN R 55 NATURE 175 379
FRAENKELCONRAT H 54 J AM CHEM SOC 76 180
SINGER B /
SCHRAMM G 55 NATURE 175 549
SCHUMACHER G /
ZILLIG W /
RICE RV 53 BIOCHIM BIOPHYS ACTA 11 337
KAESBERG P /
STAHMANN MA /
HART RG 55 P NAT ACAD SCI 41 261
TAKAHASHI WN 52 NATURE 169 419
ISHII M /
DELWICHE CC 55 BIOCHIM BIOPHYS ACTA 16 127
NEWMARK P /
TAKAHASHI WN /
NG MJ /
COMMONER B 53 SCIENCE 118 529
YAMADA M /
RODENBERG SD /
WANG FY /
BASLER E /
COHEN SS 42 J BIOL CHEM 142 863
STANLEY WM /
WILLIAMS RC 51 J AM CHEM SOC 73 2062
BACKUS RC /
STEERE RL /

GORDON AH MARTIN AJP SYNGE RLM
BIOCHEM J-M 37 R 13 43 3R 1B A 19
GR.BR.CIT BY 2. CIT 0. CIT IND BY 0. CIT IND 0
PARTITION CHROMATOGRAPHY OF FREE AMINO-ACIDS AND PEPTIDES¤¤DEVELOPED PAPER CHROMATOGRAPHY AS AN ACCURATE MEANS FOR IDENTIFICATION OF AMINO ACIDS AND PURINE-PYRIMIDINE CONTENT OF NUCLEIC ACIDS

01000
ENGLAND A 35 J AMER CHEM SOC 57 634
COHN EJ /

GORDON AH SEE CONSDEN R BIOCHEM J- 38 224
GORDON S SEE DUVIGNEA.V J A C S -L 75 4879

GRIFFITH F
J HYGIENE- 27 113 28 9R 5B 11
GR.BR.CIT BY 2. CIT 0. CIT IND BY 0. CIT IND 0
THE SIGNIFICANCE OF PNEUMOCOCCAL TYPES¤¤CHARACTERISTICS OF DEAD BACTERIA WERE TRANSFORMED TO LIVING BACTERIA GROWN IN THEIR PRESENCE

01000
*MINISTRY HEALTH
GRIFFITH F 22 13 REP PUBL HEALTH M¤
GRIFFITH F 23 18 REP PUBL HEALTH M¤
HEIDELBERGER M J EXP MED 38 73
AVERY OT /
HEIDELBERGER M J EXP MED 40 301
AVERY OT /
BAIL 17 CENTRALBL BAKT ORIG 79 425
MADLEY P 27 J INFECTIOUS DISEASE 40 1

GRUNBERG.M OCHOA S
J A C S -L 77 3165 55 20R 12B A 32
U.S.A.CIT BY 1. CIT 3. CIT IND BY 4. CIT IND 2
ENZYMATIC SYNTHESIS AND BREAKDOWN OF POLYNUCLEOTIDES - POLYNUCLEOTIDE PHOSPHORYLASE¤¤ISOLATION OF ENZYME POLYNUCLEOTIDE PHOSPHORYLASE FOR SYNTHESIS OF RNA

11000
*NYU COLLEGE MED
PUB HEALTH SERV
AMER CANCER SOC
ROCKEF F
OFFICE NAVAL RES
GRUNBERGMANAGO M / 55 FED P 14 221
OCHOA S /
COHN WE 50 J AM CHEM SOC 72 1471
KREBS HA 53 BIOCHEM BIOPHYS ACTA 12 172
HEMS R /
VISCHER E 48 J BIOL CHEM 176 715
CHARGAFF E /
CARTER CE 50 J AM CHEM SOC 72 1466
GULLAND JM 38 BIOCHEM J 32 590
JACKSON EM /
MURST RO 51 J BIOL CHEM 193 91
BUTLER GC /
SCHUSTER L 53 J BIOL CHEM 201 535
KAPLAN NO /
HEPPEL LA PERSONAL COMMUNICATI¤
PLAUT GWE 55 FEDERATION P 14 263
LOHMANN K 26 BIOCHEM Z 178 419
JENDRASSIK L /
KALCKAR HM 47 J BIOL CHEM 167 429

GRUNBERG.M ORTIZ PJ OCHOA S
SCIENCE - 122 907 55 45R 25B B 32
U.S.A.CIT BY 1. CIT 3. CIT IND BY 4. CIT IND 2
ENZYMATIC SYNTHESIS OF NUCLEIC ACIDLIKE POLYNUCLEOTIDES¤¤ISOLATION OF ENZYME POLYNUCLEOTIDE PHOSPHORYLASE FOR SYNTHESIS OF RNA

11000
*NYU COLLEGE MED
NAT I ART MET DIS
PUB HEALTH SERV
AMER CANCER SOC
ROCKEF F
OFFICE NAVAL RES
GRUNBERGMANAGO M / 55 J AM CHEM SOC 77 3165
OCHOA S /
GRUNBERGMANAGO M / 55 FEDERATION P 14 221
OCHOA S /
COHN WE 50 J AM CHEM SOC 72 1471
CAVALLIERI LF UNPUBLISHED EXPERIME¤
ROSOFF M /
VISCHER E 48 J BIOL CHEM 176 715
CHARGAFF E /
CARTER CE 50 J AM CHEM SOC 72 1466
MARKHAM R 51 BIOCHEM J 49 401
SMITH JD /
COHN WE 52 S PHOSPH METABOLISM ¤ 2 339
DOHERTY DG /
VOLKIN E /
GULLAND JM 38 BIOCHEM J 32 590
JACKSON EM /
GULLAND JM 38 BIOCHEM J 32 597
JACKSON EM /
MURST RO 51 J BIOL CHEM 193 91
BUTLER GC /
SCHUSTER L 53 J BIOL CHEM 201 535
KAPLAN NO /
HEPPEL LA 53 NATURE 171 1152
MARKHAM R /
HILLMOE RJ /
HEPPEL LA 55 BIOCHEM J 60 1
WHITFELD PR /
HEPPEL LA UNPUBLISHED EXPERIME¤
MARKHAM R 52 BIOCHEM J 52 552
SMITH JD /
MARKHAM R 52 BIOCHEM J 52 558
SMITH JD /
RICH A 54 P NATL ACAD SCI US 40 759
WATSON JD /
RICH A UNPUBLISHED EXPERIME¤
ANFINSEN CB 54 J BIOL CHEM 207 201
KREBS HA 53 BIOCHIM BIOPHYS ACTA 12 172
HEMS R /
ZAMENHOF S - 52 S PHOSPH METABOLISM ¤ 2 301
PLAUT GWE 55 FEDERATION P 14 263
PINCHOT GB ALCALIGENES FAECALIS¤
BRUMMOND DO UNPUBLISHED EXPERIME¤
HOTCHKISS RD 55 HARVEY LECTURES 49 124

HECHT LI SEE HOAGLAND MB J B C - 231 241

HERSHEY AD CHASE M
J G PHYSL- 36 39 52 29R 10B 25
U.S.A.CIT BY 0. CIT 0. CIT IND BY 1. CIT IND 2
INDEPENDENT FUNCTIONS OF VIRAL PROTEIN AND NUCLEIC ACID IN GROWTH OF BACTERIOPHAGE¤¤DEMONSTRATED THAT VIRAL NUCLEIC ACID OF BACTERIOPHAGE AND NOT PROTEIN SHELL ENTERED CELL - YET BOTH COMPONENTS WERE REDUPLICATED WITHIN CELL

00100
*CARNEGIE I WASH
PUB HEALTH SERV
MICROBIOLOGICAL I
ANDERSON TF 49 BOT REV 15 464
ANDERSON TF 51 T NEW YORK ACAD SC 13 130
ANDERSON TF 52 J GEN PHYSIOL 35 657
DOERMANN AH /
BENZER S 52 J BACT 63 59
DOERMANN AH 48 47 CARN I WASH YEARB¤ 176
DOERMANN AH 49 48 CARN I WASH YEARB¤ 170
DISSOSWAY C /
DULBECCO R 52 J BACT 63 209
MERRIOTT RM 51 J BACT 61 752
HERSHEY AD 46 GENETICS 31 620
HERSHEY AD 51 50 CARN I WASH YEARB¤ 199
ROESEL C /
CHASE M /
FORMAN S /
LWOFF A 50 ANN I PASTEUR 78 711
GUTMANN A /
MAALOE O 51 P NAT ACAD SC 37 507
WATSON JD /
NOVICK A 51 SCIENCE 113 34
SZILARD L /
PRAYER CD 51 THESIS U PENNSYLVANI¤
PRICE WH 52 J GEN PHYSIOL 35 409
PUTNAM FW 50 J BIOL CHEM 182 243
KOZLOFF L /
ROUNTREE PM 51 BRIT J EXP PATH 32 341
WATSON JD 52 IN PRESS ¤
MAALOE O 52 IN PRESS ¤

HOAGLAND MB ZAMECNIK PC STEPHENS.ML
B B ACTA -L 24 215 57 10R 4B A 34
U.S.A.CIT BY 0. CIT 0. CIT IND BY 3. CIT IND 1
ENZYMATIC REACTIONS INVOLVING PUROMYCIN AND PROTEIN SYNTHESIS¤¤DISCOVERED THAT AMINO ACIDS ARE COUPLED WITH ADENYLIC ACID BEFORE INCORPORATION INTO POLYPEPTIDE CHAIN DEMONSTRATED PRESENCE OF TRANSFER RNA

00111
*HARVARD U
PUB HEALTH SERV
ATOM ENERGY COM
HOAGLAND MB 56 J BIOL CHEM 218 345
KELLER EB /
ZAMECNIK PC /
DEMOSS JA 56 BIOCHIM BIOPHYS ACTA 22 49
NOVELLI GD /
KIRBY KS 56 BIOCHEM J 64 405
LITTLEFIELD JW 57 J BIOL CHEM 224 345
KELLER EB /
KELLER EB 56 J BIOL CHEM 221 45

ZAMECNIK PC /
HECHT LI /
POTTER VR / 56 CANCER RESEARCH 16 988

HOAGLAND MB STEPHENS.ML SCOTT JF HECHT LI ZAMECNIK PC

J B C - 231 241 58 51R 228 B 34
U.S.A.CIT BY 0. CIT 0. CIT IND BY 3. CIT IND 1
A SOLUBLE RIBONUCLEIC ACID INTERMEDIATE IN PROTEIN SYNTHESIS¤¤DISCOVERED THAT AMINO ACIDS ARE COUPLED WITH ADENYLIC ACID BEFORE INCORPORATION INTO POLYPEPTIDE CHAIN . DEMONSTRATED PRESENCE OF TRANSFER RNA

00111
*HARVARD U
PUB HEALTH SERV
ATOM ENERGY COM
AMER CANCER SOC

ZAMECNIK PC / 54 J BIOL CHEM 209 337
KELLER EB / 56 J BIOL CHEM 221 45
ZAMECNIK PC /
LITTLEFIELD JW / 57 J BIOL CHEM 224 13
KELLER EB /
HOAGLAND MB 56 J BIOL CHEM 218 345
KELLER EB /
ZAMECNIK PC /
CASPERSSON TO 50 CELL GROWTH FUNCTION¤
BRACHET J 55 NUCLEIC ACIDS ¤ 2
CHARGAFF E /
DAVIDSON JE /
HOAGLAND MB 57 BIOCHIM BIOPHYS ACTA 24 215
ZAMECNIK PC /
STEPHENSON ML /
GIERER A 56 NATURE 177 702
SCHRAMM G /
KIRBY KS 56 BIOCHEM J 64 405
SCOTT JF 56 J HISTOCHEM CYTOCHEM 4 1
FRACCASTORO AP /
TAFT EB /
HOLLEY R 57 J AM CHEM SOC 79 658
BRADLEY DF 56 J AM CHEM SOC 78 5898
RICH A /
NAYYAR SN 54 J HISTOCHEM CYTOCHEM 2 282
GLICK D /
HULTIN T 56 EXP CELL RES 11 222
HULTIN T 57 EXP CELL RES 12 675
VONDERDECKEN A /
BESKOW G /
KONINGSBERGER VV 57 NED AKAD WETNSCH P B 60 144
VANDERGRINTEN CO /
OVERBEEK JT /
DAVIE EW 56 ARCH BIOCHEM BIOPHYS 65 21
KONINGSBERGER VV /
LIPMANN F /
PETERMANN ML 57 J BIOL CHEM 224 725
HAMILTON MG /
ZAMECNIK PC 57 FEDERATION P 16 275
STEPHENSON ML /
SCOTT JF /
HOAGLAND MB /
DEMOSS JA 56 P NAT ACAD SC 42 325
GFNUTH SM /
NOVELLI GD /
BERG P 57 FEDERATION P 16 152
HOAGLAND MB CURR ACT MOL BIOL ¤
ZAMECNIK PC /
STEPHENSON ML /

HURWITZ J BRESLER A DIRINGER R

B B RES C- 3 15 60 25R 108 36
U.S.A.CIT BY 3. CIT 0. CIT IND BY 0. CIT IND 1
THE ENZYMIC INCORPORATION OF RIBONUCLEOTIDES INTO POLYRIBONUCLEOTIDES AND THE EFFECT OF DNA¤¤SYNTHESIS OF MESSENGER RNA FROM CELL FRACTIONS OF DNA NUCLEOTIDE AND ENZYMES

01101
*NYU COLLEGE MED
PUB HEALTH SERV
NAT I HEALTH
DAZIAN F MED RES
JANE COFFIN FUND

ALEXANDER M 60 FED P 19 318
BRESLER A /
FURTH J /
HURWITZ J /
HURWITZ J 59 J BIOL CHEM 234 2351
KAY ERM 52 J AM CHEM SOC 74 1724
SIMMONS NS /
DOUNCE AL /
KIRBY KS 56 BIOCHEM J 64 405
KRAKOW JS 60 FED P 19 307
KAMMEN HO /
PREISS J 60 FED P 19 317
BERG P /
RAZELL WE 59 J BIOL CHEM 234 2114
KHORANA HG /
ROSE IA 54 J BIOL CHEM 211 737
GRUNBERGMANAGO M /
KOREY SR /
OCHOA S /
SINGER MF 58 FED P 17 312
HILMOE RJ /
HEPPEL LA /
WEISS SH 59 J AM CHEM SOC 81 4118
GLADSTONE L /

JACOB F MONOD J

J MOL BIO-B 3 318 61 218R 1000 35
PRAN.CIT BY 2. CIT 0. CIT IND BY 0. CIT IND 1
GENETIC REGULATORY MECHANISMS IN THE SYNTHESIS OF PROTEINS¤¤PRESENCE OF MESSENGER RNA IN BACTERIAL CELLS

01010
*I PASTEUR PARIS
NATL SCIENCE F
JANE COFFIN FUND
COM ENERG ATOMIQ

ADELBERG EA / 53 J BIOL CHEM 205 475
UMBARGER HE /
AMES BN 59 P NAT ACAD SCI WASH 45 1453
GARRY B /
AMES BN 60 J GEN MICROBIOL 22 369

GARRY B /
HERZENBERG LA /
BENZER S 53 BIOCHIM BIOPHYS ACTA 11 383
BERTANI G 53 COLD SPR HARB S QUAN 18 65
BERTANI G 58 ADVANC VIRUS RES 5 151
BRENNER S 61 NATURE 190 576
JACOB F /
MESELSON M /
BUSSARD A 60 CR ACAD SCI PARIS 250 4049
NAONO S /
GROS F /
MONOD J /
BUTTIN G 56 DIPLOME ET SUP PARIS¤
BUTTIN G 61 IN THE PRESS ¤
COHEN GN 59 CR ACAD SCI PARIS 248 3490
JACOB F /
COHEN GN 57 BACT REV 21 169
MONOD J /
COHEN SS 49 BACT REV 13 1
COHENBAZIRE G 53 ANN I PASTEUR 84 1
JOLIT M /
COHN M 57 BACT REV 21 140
COHN M 53 CR ACAD SCI PARIS 236 746
COHEN GN /
MONOD J /
COHN M 59 J BACT 78 624
HORIBATA K /
COHN M 53 ADAPT MICROORGANISMS¤ 132
MONOD J /
COHN M 52 J IMMUNOL 69 471
TORRIANI AM /
DAVERN CI 60 J MOL BIOL 2 153
MESELSON M /
DEMEREC M 56 COLD SPR HARB S QUAN 21 113
DIENERT F ANN I PASTEUR 14 139
DUCLAUX E 99 TRAITE MICROBIOLOGIE¤
ECHOLS H 61 IN THE PRESS ¤
GAREN A /
GAREN S /
TORRIANI AM /
FLAKS JG 59 J BIOL CHEM 234 1501
COHEN SS /
GALE EF 43 BACT REV 7 139
GILES NH 58 10 P INT C GENET ¤ 1 261
GORINI L 57 BIOCHIM BIOPHYS ACTA 25 208
MAAS WK /
GORINI L 58 CHEM BASIS DEVELOP ¤ 469
MAAS WK /
GROS F 61 NATURE 190 581
HIATT H /
GILBERT W /
KURLAND CG /
RISEBROUGH RW /
WATSON JD /
HALVORSON HO 60 IN THE PRESS ¤
HARTMAN PE 60 J GEN MICROBIOL 22 323
LOPER JC /
SERMAN D /
HERZENBERG L 59 BIOCHIM BIOPHYS ACTA 31 325
HOGNESS DS 55 BIOCHIM BIOPHYS ACTA 16 99
COHN M /
MONOD J /
JACOB F 54 BACT LYSOG PROVIRUS ¤
JACOB F 60 HARVEY LECTURES 54 1
JACOB F 59 CR ACAD SCI PARIS 249 189
ADELBERG FA /
JACOB F 59 CR ACAD SCI PARIS 248 3219
CAMPBELL A /
JACOB F 57 ANN I PASTEUR 93 724
FUERST CR /
WOLLMAN EL /
JACOB F 59 CR ACAD SCI PARIS 249 1282
MONOD J /
JACOB F 60 CR ACAD SCI PARIS 250 1727
PERRIN D /
SANCHEZ C /
MONOD J /
JACOB F 60 10 S SOC GEN MICR ¤ 67
SCHAEFFER P /
WOLLMAN EL /
JACOB F 53 COLD SPR HARB S QUAN 18 101
WOLLMAN EL /
JACOB F 56 ANN I PASTEUR 91 486
WOLLMAN EL /
JACOB F 57 CHEM BASIS HEREDITY ¤ 468
WOLLMAN EL /
KAISER AD 57 VIROLOGY 3 42
KAISER AD 57 VIROLOGY 4 509
JACOB F /
KALCKAR HM 59 P NAT ACAD SCI WASH 45 1776
KURAHASHI K /
JORDAN E /
KARSTROM H 38 ERGEBN ENZYMFORSCH 7 350
KEPES A 60 BIOCHIM BIOPHYS ACTA 40 70
KEPES A 61 IN PREPARATION ¤
MONOD J /
JACOB F /
KOGUT M 56 BIOCHEM J 62 391
POLLOCK M /
TRIDGELL EJ /
KORNBERG A 59 P NAT ACAD SCI WASH 45 772
ZIMMERMAN SB /
KORNBERG SR /
JOSSE J /
KRUH J 61 IN THE PRESS ¤
ROSA J /
OREYFUS JC /
SCHAPIRA G /
LAMFROM H 61 J MOL BIOL 3 241
LEDERBERG E 60 10 S SOC GEN MICR ¤ 115
LEVINTHAL C 59 BROOKHAVEN S BIOL ¤ 76
LURIA SE 50 J BACT 59 551
HUMAN ML /
LWOFF A 53 BACT REV 17 269
LWOFF A 50 ANN I PASTEUR 79 815
SIMINOVITCH L /
KJELDGAARD N /
MAGASANIK B 59 CIBA S REG CELL METAB 334
MAGASANIK AK /
NEIDHARDT FC /
MONOD J 42 RECH CROISS CULT BAC¤
MONOD J 55 EXP ANN BIOCHIM M 17 193
MONOD J 56 UNITS BIOL STRUCT FUN¤ 7
MONOD J 58 REC TRAV CHIM PAYSBA 77 569
MONOD J 59 ANGEW CHEM 71 693
MONOD J 46 ANN I PASTEUR 72 868

AUDUREAU A /
MONOD J 53 CR ACAD SCI PARIS 236 530
COHENBAZIRE G /
MONOD J 52 ADVANC ENZYMOL 13 67
COHN M /
MONOD J 53 6 INTERN C MICROBIOL¤ 42
COHN M /
MONOD J 52 BIOCHIM BIOPHYS ACTA 9 648
PAPPENHEIMER AM /
COHENBAZIRE G /
MONOD J 47 ANN I PASTEUR 73 937
WOLLMAN EL /
NAONO S 60 CR ACAD SCI PARIS 250 3527
GROS F /
NAONO S 60 CR ACAD SCI PARIS 250 3889
GROS F /
NEIDHARDT FC 56 NATURE 178 801
MAGASANIK B /
NEIDHARDT FC 56 BIOCHIM BIOPHYS ACTA 21 324
MAGASANIK B /
NOVICK A 55 ANN REV MICROBIOL 9 97
SZILARD L /
PARDEE AB 57 J BACT 73 376
PARDEE AB 59 J MOL BIOL 1 165
JACOB F /
MONOD J /
PARDEE AB 59 BIOCHIM BIOPHYS ACTA 36 545
PRESTIDGE LS /
PARDEE AB 61 IN PREPARATION ¤
PRESTIDGE LS /
PERRIN D 59 CR ACAD SCI PARIS 249 778
BUSSARD A /
MONOD J /
PERRIN D 60 CR ACAD SCI PARIS 250 155
JACOB F /
MONOD J /
POLLOCK M 50 BRIT J EXP PATHOL 4 739
POLLOCK M 51 BRIT J EXP PATHOL 5 387
PERRET JC /
PONTECORVO G 58 TRENDS GEN ANALYSIS ¤
RICKENBERG HV 56 ANN I PASTEUR 91 829
COHEN GN /
BUTTIN G /
MONOD J /
RILEY M 60 J MOL BIOL 2 216
PARDEE AB /
JACOB F /
MONOD J /
ROTMAN B 54 J BACT 68 419
SPIEGELMAN S /
SIMINOVITCH L 52 ANN I PASTEUR 83 745
JACOB F /
STANIER RY 51 ANN REV MICROBIOL 5 35
SZILARD L 60 P NAT ACAD SCI WASH 46 277
TORRIANI AM 60 BIOCHIM BIOPHYS ACTA 38 460
UMBARGER HE 56 SCIENCE 123 848
VOGEL HJ 57 P NAT ACAD SCI WASH 43 491
VOGEL HJ 57 CHEM BASIS HEREDITY ¤ 276
VOLKIN E 57 CHEM BASIS HEREDITY ¤ 686
ASTRACHAN L /
WENT FC 01 J WISS BOT 36 611
WIJESUNDERA S 53 BIOCHEM J 55 R 8
WOODS DD /
WILLSON C 61 IN PREPARATION ¤
PERRIN D /
JACOB F /
MONOD J /
WOLLMAN EL 59 SEXUALITE BACTERIES ¤
JACOB F /
YANOFSKY C 60 BACT REV 24 221
YANOFSKY C 59 VIROLOGY 8 425
LENNOX ES /
YARMOLINSKY MB 60 IN THE PRESS ¤
WIESMEYER H /
YATES RA 56 J BIOL CHEM 221 757
PARDEE AB /
YATES RA 57 J BIOL CHEM 227 677
PARDEE AB /
YCAS M 60 P NAT ACAD SCI WASH 46 804
VINCENT WS /
ZABIN I 59 BIOCHEM BIOPHYS RES 1 289
KEPES A /
MONOD J /

JACOBS WA SEE LEVENE PA BER CHEM - 42 2102
JACOBS WA SEE LEVENE PA BER CHEM - 42 3247
JONES ON SEE NIRENBER.MW P N A S - 48 104

KAMEYAMA T NOVELLI GD
P N A S - 48 659 62 43R 170 C 38
U.S.A.CIT BY 0. CIT 2. CIT IND BY 0. CIT IND 1
THE SYNTHESIS OF BETA-GALACTOSIDASE BY A CELL-FREE PREPARATION FROM ESCHERICHIA COLI¤¤MANUFACTURED MESSENGER RNA FROM CELL FRAGMENTS AND USED IT AS A MODEL IN THE FORMATION OF BETA-GALACTOSIDASE

01010
*OAKRIDGE NAT LAB
KAMEYAMA T 60 BACTERIOL P 148
NOVELLI GD /
COWIE DB 61 P NATL ACAD SCI 47 114
SPIEGELMAN S /
ROBERTS RB /
DUERKSON JD /
GALE EF 56 3 P INTERN C BIOCHEM¤ 345
LIEBECO C /
SPIEGELMAN S 57 CHEMICAL BASIS HERED¤ 232
MCELROY WD /
GLASS B /
NISMAN B 59 COMPT REND 249 2240
FUKUHARA H /
KAMEYAMA T 60 BIOCHEM BIOPHYS RESE 2 393
NOVELLI GD /
WALLENFELS K 60 BIOCHEM Z 332 247
ARENS A /
LEDERBERG J 50 J BACTERIOL 60 381
SIEKEVITZ P 52 J BIOL CHEM 195 549
LOWRY OH 51 J BIOL CHEM 193 265
ROSEBROUGH NJ /
FAAR AL /
RANDALL RJ /
KAMEYAMA T IN PRESS ¤
NOVELLI GD /
NODA L 55 METHODS ENZYMOLOGY ¤ 2 605
KUBY S /

LARDY H /
COLOWICK SP /
KAPLAN NO /
NISMAN B 60 COMPT REND 250 410
FUKUHARA H /
TISSIERES A 60 P NATL ACAD SCI 46 1450
SCHLESSINGER D /
GROS F /
MATTHAEI JH 61 FEDERATION P 20 391
NIRENBERG MW /
ALLFREY VG 58 P NATL ACAD SCI 44 981
MIRSKY AE /
EISENSTADT JM 62 P NATL ACAD SCI 48 652
KAMEYAMA T /
NOVELLI GD /

KAMEYAMA T SEE EISENSTA.JM P N A S - 48 652
KAMEYAMA T SEE NOVELLI GD SCIENCE -L 133 1369
KATSOYAN.PG SEE DUVIGNEA.V J A C S -L 75 4879

KORNBERG A LEHMAN IR SIMMS ES
FED PROC -M 15 291 56 2R 18 A 33
U.S.A.CIT BY 1. CIT 1. CIT IND BY 1. CIT IND 0
POLYDESOXYRIBONUCLEOTIDE SYNTHESIS BY ENZYMES FROM ESCHERICHIA COLI¤¤ENZYMIC SYNTHESIS OF DNA FROM DEOXYNUCLEOTIDES

01010
*WASH U SCH MED
FRIEDKIN M 54 FEDERATION P 13 214

KORNBERG A LEHMAN IR BESSMAN MJ SIMMS ES
B B ACTA -L 21 197 56 13R 48 B 33
U.S.A.CIT BY 1. CIT 1. CIT IND BY 1. CIT IND 0
ENZYMIC SYNTHESIS OF DEOXYRIBONUCLEIC ACID¤¤ENZYMIC SYNTHESIS OF DNA FROM DEOXYNUCLEOTIDES

01010
*WASH U SCH MED
AMER CANCER SOC
NAT SCIENCE F
PUB HEALTH SERV
KORNBERG A 56 FEDERATION P 15 291
LEHMAN IR /
SIMMS ES /
SABLE HZ 54 BIOCHIM BIOPHYS ACTA 13 156
WILBER PB /
COHEN AE /
KANE MR /
HECHT LI 54 BIOCHIM BIOPHYS ACTA 15 134
POTTER VR /
HERBERT E /
POTTER RL 55 J AM CHEM SOC 77 6714
SCHLESINGER S /

KORNBERG A
JHU MCP I- 153 579 57 267R 1148 C 33
U.S.A.CIT BY 1. CIT 1. CIT IND BY 1. CIT IND 0
PATHWAYS OF ENZYMATIC SYNTHESIS OF NUCLEOTIDES AND POLYNUCLEOTIDES¤¤ENZYMIC SYNTHESIS OF DNA FROM DEOXYNUCLEOTIDES

01010
*WASH U SCH MED
AMER CANCER SOC
NAT SCIENCE F
PUB HEALTH SERV
ABRAMS R 55 J AM CHEM SOC 77 4179
BENTLEY M /
ABRAMS A 51 ARCH BIOCHEM BIOPHYS 34 285
KLENOW H /
AGRANOFF BW 56 J BIOL CHEM 219 221
BRADY RO /
BEERS RF 56 NATURE 177 790
BENTLEY M 56 FEDERATION P 15 218
ABRAMS R /
BERG P 55 J AM CHEM SOC 77 3163
BERG P 56 FEDERATION P 15 219
NEWTON G /
BERGKVIST R 53 ACTA CHEM SCAND 7 1307
DEUTSCH A /
BRAWERMAN G 53 J AM CHEM SOC 75 2020
CHARGAFF E /
BRAWERMAN G 53 J AM CHEM SOC 75 4113
CHARGAFF E /
BROWN GB 55 NUCLEIC ACIDS ¤ 2 341
ROLL PM /
CHARGAFF E /
DAVIDSON JN /
BUCHANAN JM 52 PHOSPHORUS METAB ¤ 2 406
MCELROY WD /
GLASS B /
CANELLAKIS ES 56 FEDERATION P 15 229
CAPUTTO R 51 J BIOL CHEM 189 801
CARDINI CE 50 ACTA PHYSIOL LATINOA 1 57
PALADINI AC /
CAPUTTO R /
LELOIR LF /
CARTER CE 51 J AM CHEM SOC 73 1237
CARTER CE 56 FEDERATION P 15 230
CARTER CE 55 J AM CHEM SOC 77 499
COHEN LH /
COHEN SS 51 FEDERATION P 10 173
SCOTT DBM /
LANNING M /
COLOWICK SP 43 J BIOL CHEM 148 117
KALCKAR HM /
CRAWFORD I UNPUB ¤
KORNBERG A /
GLOCK GE 52 B MICR FAC PHAR NANC 1
DELEY J CITED INDIRECTLY ¤
FRIEDKIN M 50 J BIOL CHEM 184 449
FRIEDKIN M 53 J CELL COMP PHYSI 51 261
FRIEDKIN M 54 J BIOL CHEM 209 295
FRIEDKIN M 50 J BIOL CHEM 184 437
KALCKAR HM /
FRIEDKIN M 55 FEDERATION P 14 215
ROBERTS D /
FRIEDKIN M 54 FEDERATION P 13 214
WILLSON D /
ROBERTS D /
GLOCK GE 55 NUCLEIC ACIDS ¤ 2 248
CHARGAFF E /
DAVIDSON JN /
GOLDTHWAIT DA 56 FEDERATION P 15 263

GOLDTHWAIT DA / GREENBERG GR / PEABODY RA / GREENBERG GR 54 FEDERATION P 13 745
GREENBERG GR 56 J BIOL CHEM 219 423
GRUNBERGMANAGO M 55 J AM CHEM SOC 77 3165
OCHOA S /
GRUNBERGMANAGO M 55 SCIENCE 122 907
ORTIZ PJ /
OCHOA S /
GRUNBERGMANAGO M 56 BIOCHIM BIOPHYS ACTA 20 269
ORTIZ PJ /
OCHOA S /
GUARINO AJ 55 J BIOL CHEM 215 515
SABLE HZ /
HAMMARSTEN E 50 J BIOL CHEM 183 105
REICHARD P /
SALUSTE E /
HARTMAN SC 55 J AM CHEM SOC 77 501
LEVENBERG B /
BUCHANAN JM /
HECHT LI 54 BIOCHIM BIOPHYS ACTA 15 134
POTTER VR /
HERBERT E /
HERBERT E 55 J BIOL CHEM 213 923
POTTER VR /
TAKAGI Y /
HOAGLAND MB 54 J BIOL CHEM 207 767
NOVELLI GD /
HORECKER BL 55 ANN REVS BIOCHEM 24 207
MEHLER AH /
HORECKER BL 51 J BIOL CHEM 193 383
SMYRNIOTIS PZ /
SEEGMILLER JE /
HURLBERT RB 54 J BIOL CHEM 2(1
POTTER VR /
HURLBERT RB 55 ACTA CHEM SCAND 9 251
REICHARD P /
JONES ME 55 J AM CHEM SOC 77 819
SPECTOR L /
LIPMANN F /
KALCKAR HM 43 J BIOL CHEM 148 127
KALCKAR HM 47 J BIOL CHEM 167 477
KENNEDY EP 55 J AM CHEM SOC 77 250
WEISS SB /
KLENOW H 53 ARCH BIOCHEM BIOPHYS 46 186
KORN ED 55 J BIOL CHEM 217 183
BUCHANAN JM /
KORN ED 53 J AM CHEM SOC 75 3610
CHARALAMPOUS FC /
BUCHANAN JM /
KORN ED 55 J BIOL CHEM 217 875
REMY CN /
WASILEJKO HC /
BUCHANAN JM /
KORNBERG A 48 J BIOL CHEM 176 1475
KORNBERG A 50 J BIOL CHEM 182 779
KORNBERG A 51 PHOSPHORUS METAB ¤ 1 392
MCELROY WD /
GLASS B /
KORNBERG A 56 BIOCHIM BIOPHYS ACTA 21 197
LEHMAN IR /
BESSMAN MJ /
SIMMS ES /
KORNBERG A 56 FEDERATION P 15 291
LEHMAN IR /
SIMMS ES /
KORNBERG A 54 J AM CHEM SOC 76 2027
LIEBERMAN I /
SIMMS ES /
KORNBERG A 55 J BIOL CHEM 215 389
LIEBERMAN I /
SIMMS ES /
KORNBERG A 55 J BIOL CHEM 215 417
LIEBERMAN I /
SIMMS ES /
KORNBERG A 51 J BIOL CHEM 191 535
PRICER WE /
KORNBERG A 51 J BIOL CHEM 193 481
PRICER WE /
KOSHLAND DE 54 MECH ENZYME ACTION ¤ 608
MCELROY WD /
GLASS B /
LAGERKVIST U 55 ACTA CHEM SCAND 9 1028
LAMPEN JO 52 PHOSPHORUS METAB ¤ 2 363
MCELROY WD /
GLASS B /
LAMPEN JO 53 J CELL COMP PHYSI S1 41 183
LEVENBERG B 56 J AM CHEM SOC 78 504
BUCHANAN JM /
LEVENBERG B 56 FEDERATION P 15 117
MELNICK I /
LIEBERMAN I 55 J AM CHEM SOC 77 2661
LIEBERMAN I 56 J AM CHEM SOC 78 253
LIEBERMAN I 53 BIOCHIM BIOPHYS ACTA 12 223
KORNBERG A /
LIEBERMAN I 54 J BIOL CHEM 207 911
KORNBERG A /
LIEBERMAN I 55 J BIOL CHEM 212 909
KORNBERG A /
LIEBERMAN I 54 J AM CHEM SOC 76 2844
KORNBERG A /
SIMMS ES /
LIEBERMAN I 54 J AM CHEM SOC 76 3608
KORNBERG A /
SIMMS ES /
LIEBERMAN I 55 J BIOL CHEM 215 403
KORNBERG A /
SIMMS ES /
LIPTON SH 53 J AM CHEM SOC 75 5449
MORELL SA /
FRIEDEN A /
BOCK RM /
LITTAUER UZ 56 FEDERATION P 15 302
LITTAUER UZ UNPUB ¤
KORNBERG A /
LUKENS LN 56 FEDERATION P 15 305
BUCHANAN JM /
MACNUTT WS 52 BIOCHEM J LONDON 50 384
MAGASANIK B 55 NUCLEIC ACIDS ¤ 1 373
CHARGAFF E /
DAVIDSON JN /
MANSON LA 51 J BIOL CHEM 191 95
LAMPEN JO /
MANSON LA 51 J BIOL CHEM 193 539
LAMPEN JO /

MICHELSON AM 51 P NATL ACAD SCI US 37 396
DRELL W /
MITCHELL HK /
MITCHELL HK 48 J BIOL CHEM 172 525
MOULAHAN MB /
NYC JF /
MOYED HS 56 FEDERATION P 15 318
MAGASANIK B /
MUNCHPETERSEN A 54 ACTA CHEM SCAND 8 1102
MUNCHPETERSEN A 55 ARCH BIOCHEM BIOPHYS 55 592
MUNCHPETERSEN A 53 NATURE 172 1036
KALCKA HM /
CUTOLO E /
SMITH EEB /
PAEGE LM 50 ARCH BIOCHEM 28 348
SCHLENK F /
PAEGE LM 52 ARCH BIOCHEM BIOPHYS 40 42
SCHLENK F /
POTTER RL 55 J AM CHEM SOC 77 6714
SCHLESINGER S /
RABINOWITZ JC 56 J BIOL CHEM 218 175
RABINOWITZ JC 56 J BIOL CHEM 281 147
BARKER HA /
RABINOWITZ JC 56 J BIOL CHEM 281 161
BARKER HA /
RABINOWITZ JC 56 FEDERATION P 15 332
PRICER WE /
RABINOWITZ JC 56 J BIOL CHEM 218 189
PRICER WE /
RACKER E 52 J BIOL CHEM 196 347
RACKER E 54 ADVANCES ENZYMOL 15 141
RACKER E 54 ARCH BIOCHEM BIOPHYS 48 238
DELAHABA G /
LEDER IG /
REICHARD P 55 ACTA CHEM SCAND 9 1275
REICHARD P 55 NUCLEIC ACIDS ¤ 2 277
CHARGAFF E /
DAVIDSON JN /
REICHARD P 51 J BIOL CHEM 188 839
ESTBORN B /
REICHARD P 55 ACTA CHEM SCAND 9 1010
SMITH LH /
HANSHOFF G /
REMY CN 55 J BIOL CHEM 217 885
REMY WT /
BUCHANAN JM /
ROLL PM 56 J BIOL CHEM 220 455
WEINFELD H /
CARROLL E /
ROSE IA 53 J BIOL CHEM 202 635
SCHWEIGERT BS /
SABLE HZ 52 BIOCHIM BIOPHYS ACTA 8 687
SABLE HZ 54 BIOCHIM BIOPHYS ACTA 13 156
WILBER PB /
COHEN AE /
KANE MR /
SCHLENK F 55 NUCLEIC ACIDS ¤ 2 309
CHARGAFF E /
DAVIDSON JN /
SCHMITZ H 54 J BIOL CHEM 209 41
HURLBERT RB /
POTTER VR /
SCHRECKER AW 50 J BIOL CHEM 182 795
KORNBERG A /
STROMINGER JL 54 ARCH BIOCHEM BIOPHYS 52 488
HEPPEL LA /
MAXWELL ES /
WAJZER J 49 B SOC CHIM BIOL 31 750
BARON F /
WARREN L 56 FEDERATION P 15 379
FLAKS JG /
WELCH AD 56 ENZYMES UNITS BIOLOG¤
GAEBLER OH /
WILLIAMS WJ 53 J BIOL CHEM 203 583
BUCHANAN JM /
WRIGHT LD 53 P SOC EXPTL BIOL MED 84 716
DRISCOLL CA /
MILLER CS /
SKEGGS HR /
WRIGHT LD 54 P SOC EXPTL BIOL MED 86 215
MILLER CS /
DRISCOLL CA /

KOSSEL A
2 PHYSL C- 10 248 86 9R 88 5
GERM CIT BY 0, CIT IN 1, CIT IND BY 1. CIT IND 0
WEITERE BEITRAGE ZUR CHEMIE DES
ZELLKERNS¤¤ISOLATED THE PURINE AND PYRIMIDINE
CONTENT OF NUCLEIC ACIDS

00110
*PHYSIO- J BERLIN
MIESCHER F 71 MEDICINISCH CHEMISCH¤ 502
BUNGE G 84 Z PHYSIOL CHEM 9 49
TICHOMIROFF A 85 Z PHYSIOL CHEM 9 51
WEIDEL H 85 Z PHYSIOL CHEM 9 52
STAECKER O 58 ANNALEN CHEM PHARM 32 141
FISCHER E 82 ANNALEN CHEM PHARM 215 309
KOSSEL A 82 Z PHYSIOL CHEM 6 429
KOSSEL A 84 Z PHYSIOL CHEM 8 404

LAMLER MC SEE DNVICINEA-V J A C S -1- 75 4880
LEHMAN IR SEE KORNBERG A B B A CTA -1- 21 197
LEHMAN IR SEE KORNBERG A FED PROC -1- 15 241

LEVENE PA JACOBS WA
BER CHEM - 42 2102 09 9R 38 A 9
GERM CIT BY 0, CIT IN 1, CIT IND BY 1. CIT IND 0
ÜBER DIE PENTOSE IN DEN NUCLEINSÄUREN¤¤IDENTIT
Y OF RIBOSE AS THE CARBOHYDRATE COMPONENT OF
NUCLEIC ACID

00110
*ROCKEF I MED RES
NEUBERG C 02 BER CHEM GES 35 1467
NEUBERG C 07 BIOCHEM Z 5 438
BRAHM B /
HAISER F 09 MONATSH CHEM 30 147
WENZEL F /
LEVENE PA 08 BIOCHEM Z 10 221
MANDEL JA /
BOOS 08 J BIOL CHEMISTRY 9 469

LEVENE PA JACOBS WA
BER CHEM - 42 3247 09 10R 5B B 9
U.S.A.CIT BY 0. CIT 1. CIT IND BY 1. CIT IND 0
UBER DIE PENTOSE IN DEN NUCLEINSAUREN .2.
MITTEILUNG¤¤IDENTITY OF RIBOSE AS THE CARBOHYDRATE COMPONENT OF NUCLEIC ACID

00110
*ROCKEF I MED RES
LEVENE PA / 09 BER CHEM GES 42 2102
JACOBS WA /
HAISER F / 09 MONATSH CHEM 30 377
WENZEL F /
FISCHER E / 91 BER CHEM GES 24 4214
PILOTY O /
NEUBERG C / 99 BER CHEM GES 32 3384
VANEKENSTEIN A / 02 CHEMISCH WEEKBLAD
BLANKSMA JJ /

LEVENE PA LONDON ES
J B C - 83 793 29 24R 11B A 12
U.S.A.CIT BY 1. CIT 0. CIT IND BY 2. CIT IND 2
THE STRUCTURE OF THYMONUCLEIC ACID¤¤PRESENCE OF DEOXYRIBOSE IN THYMONUCLEIC ACID ALSO TETRANUCLOTIDE HYPOTHESIS

01100
*ROCKEF I MED RES
LEVENE PA / 08 BER CHEM GES 41 1905
MANDEL JA /
LEVENE PA / 12 J BIOL CHEM 12 411
JACOBS WA /
THANNHAUSER SJ / 21 Z PHYSIOL CHEM 114 39
OTTENSTEIN B /
THANNHAUSER SJ / 26 Z PHYSIOL CHEM 161 116
BLANCO G /
LEVENE PA / 29 J BIOL CHEM 81 711
LONDON ES /
JONES W 20 NUCLEIC ACIDS ¤
FEULGEN R 23 CHEMIE PHYSIOLOGIE N¤
LEVENE PA 29 J BIOL CHEM 83 803
MORI T /
FEULGEN R 22 Z PHYSIOL CHEM 123 197
LEVENE PA 08 BIOCHEM Z 10 215
MANDEL JA /
LEVENE PA / 11 J BIOL CHEM 9 65
MEDIGRECEANU F /
LEVENE PA / 11 J BIOL CHEM 9 375
MEDIGRECEANU F /
LEVENE PA / 11 J BIOL CHEM 9 389
MEDIGRECEANU F /

LEVENE PA MORI T
J B C - 83 803 29 12R 6B B 12
U.S.A.CIT BY 1. CIT 0. CIT IND BY 2. CIT IND 2
RIBODESOSE AND XYLODESOSE AND THEIR BEARING ON THE STRUCTURE OF THYMINOSE¤¤PRESENCE OF DEOXYRIBOSE IN THYMONUCLEIC ACID ALSO TETRANUCLEOTIDE HYPOTHESIS

01100
*ROCKEF I MED RES
MEISENHEIMER J / 27 BER CHEM GES 60 1462
JUNG H /
KIERMAYER J 95 CHEM ZTG 19 1004
VANEKENSTEIN A 10 BER CHEM GES 43 2355
BLANKSMA JJ /
PUMMERER R 23 BER CHEM GES 56 999
GUMP W /
LEVENE PA / 29 J BIOL CHEM 81 711
LONDON ES /
GEHRKE M / 27 BER CHEM GES 60 918
AICHNER FX /

LEVENE PA TIPSON RS
J B C - 109 623 35 11R 5B 15
U.S.A.CIT BY 0. CIT 1. CIT IND BY 2. CIT IND 0
THE RING STRUCTURE OF THYMIDINE¤¤PROPOSED TRUE STRUCTURE OF DNA

01000
*ROCKEF I MED RES
LEVENE PA / 29 J BIOL CHEM 81 711
LONDON ES /
LEVENE PA / 29 J BIOL CHEM 83 793
LONDON ES /
BERGMANN M / 29 ANN CHEM 470 51
BREUERS W /
LEVENE PA / 30 J BIOL CHEM 88 791
MIKESKA LA /
LEVENE PA / 34 J BIOL CHEM 105 419
TIPSON RS /

LONDON ES SEE LEVENE PA J B C - 83 793
MACLEOD CN SEE AVERY OT J EX MED - 79 137
MARTIN AJP SEE CONSDEN R BIOCHEM J- 38 224
MARTIN AJP SEE GORDON AH BIOCHEM J-M 37 R 15

MATTHAEI JH NIRENBER.MW
P N A S - 47 1580 31R 13B A 40
U.S.A.CIT BY 0. CIT 1. CIT IND BY 0. CIT IND 3
CHARACTERISTICS AND STABILIZATION OF DNAASE-SENSITIVE PROTEIN SYNTHESIS IN E COLI EXTRACTS¤¤USED POLYURIDYLIC ACID IN CELL FREE SYSTEM TO PRODUCE A PROTEIN COMPOSED ONLY OF PHENYLALANINE . THE FIRST STEP IN BREAKING THE GENETIC CODE

01100
*NAT I HEALTH
TISSIERES A / 60 P NATL ACAD SCI 46 1450
SCHLESSINGER D /
GROS F /
MATTHAEI JH / 61 FED P 20 391
NIRENBERG MW /
KAMEYAMA T / 60 BIOCHEM BIOPHYS RES 2 393
NOVELLI GD /
KIRSCH JF / 60 J BIOL CHEM 235 1419
SIEKEVITZ P /
PALADE GE /
NOMA BY / 59 J AM CHEM SOC 81 4449
MERLER E /
MAURY P /
ANSON ML 38 J GEN PHYSIOL 22 79
SEVAG MG 38 J BIOL CHEM 124 425
LACKMANN DB /
SMOLENS J /
LOWRY OH / 51 J BIOL CHEM 193 265
ROSEBROUGH NJ /
FARR AL /
RANDALL RJ /
ALLFREY VG 58 P NATL ACAD SCI 44 981
MIRSKY AE /
HURWITZ J 60 BIOCHEM BIOPHYS RES 3 15
BRESLER A /
DIRINGER R /
STEVENS A 60 BIOCHEM BIOPHYS RES 3 92
WEISS SB 61 J BIOL CHEM 236 PC18
NAKAMOTO T /
SIEKEVITZ P 52 J BIOL CHEM 195 549

MATTHAEI JH SEE NIRENBER.MW P N A S - 47 1588
MATTHAEI JH SEE NIRENBER.MW P N A S - 48 104
MCCARTY M SEE AVERY OT J EX MED - 79 137

MENDEL G
VERH NAT - 10 3 65 1R B 2
AUSTR.CIT BY 0. CIT 0. CIT IND BY 1. CIT IND 0
VERSUCHE UBER PFLANZEN-HYBRIDEN¤¤FIRST DEMONSTRATION OF LAWS OF SIMPLE INHERITANCE

00010

MICHELSu.AM TODD AR
J CHEM S - 2632 55 32R 13B 29
GR.BR.CIT BY 0. CIT 0. CIT IND BY 1. CIT IND 2
NUCLEOTIDES .32. SYNTHESIS OF A DITHYMIDINE DINUCLEOTIDE CONTAINING A 3¤-5¤-INTERNUCLEOTIDIC LINKAGE¤¤SYNTHESIS OF NUCLEIC ACID IN VERIFICATION OF LEVENES SUGGESTED FORMULA

00101
*U CAMBRIDGE
MICHELSON AM / 53 J CHEM SOC 951
TODD AR /
MICHELSON AM / 54 J CHEM SOC 34
TODD AR /
HAYES DM / 55 J CHEM SOC 808
MICHELSON AM /
TODD AR /
CARTER CE 51 J AMER CHEM SOC 73 1537
BROWN DM 52 J CHEM SOC 52
TODD AR /
DEKKER CA / 53 J CHEM SOC 947
MICHELSON AM /
TODD AR /
SMITH JD / 52 BIOCHIM BIOPHYS ACTA 8 350
MARKHAM R /
SINSHEIMER RL 54 J BIOL CHEM 208 444
CHRISTIE SMH 53 J CHEM SOC 2947
ELMORE DT /
KENNER GW /
TODD AR /
WEYMOUTH FJ /
MICHELSON AM / 55 J CHEM SOC 816
TODD AR /
CORBY NS 52 J CHEM SOC 3669
KENNER GW /
TODD AR /
MICHELSON AM / 53 J CHEM SOC 951
TODD AR /
BEALE RN 50 J CHEM SOC 1397
HARRIS RJC /
ROE EMF /

NIESCHER F
H-S M C U- 460 441 71 8R 6B 3
GERM. CIT BY 3. CIT 0. CIT IND BY 0. CIT IND 0
UEBER DIE CHEMISCHE ZUSAMMENSETZUNG DER EITERZELLEN¤¤DISCOVERY OF NUCLEIC ACID

01100
*U BASEL
HOPPESEYLER F HANDBUCH PHYS CHEM ¤ 363
ROVIDA SITZ WIENER AKAD ¤ 56
PARKE MEDICINISCH CHEMISCH¤ 11 213
FISCHER E 65 MED CENTRALBLATT 225
BODECKER 58 Z RATIONELLE MEDICIN 6 196
KUHNE W VIRCH ARCH 33 66
RUDNEW

MIRSKY AE SEE SIBATANI A P N A S - 48 471
MONOD J SEE JACOB F J MOL BIO-R 3 318
MORI T SEE LEVENE PA J B C - 83 803

MULLER HJ DIPPEL AL
BR J EX B-B - 3 35 26 27R 19B 10
U.S.A.CIT BY 0. CIT 0. CIT IND BY 1. CIT IND 0
CHROMOSOME BREAKAGE BY X-RAYS AND THE PRODUCTION OF EGGS FROM GENETICALLY MALE TISSUE IN DROSOPHILA¤¤RADIATION USED TO ALTER GENES AND PRODUCE MUTATIONS

00010
*U TEXAS
BRIDGES CB 21 SCIENCE N S 53 308
BRIDGES CB 21 SCIENCE N S 54 252
BRIDGES CB 23 ANAT REC 24 426
CROWTHER JA 24 P ROY SOC LOND B 96 207
LITTLE CC 23 AMER J ROENT 10 975
BAGG HJ /
LITTLE CC 24 J EXP ZOOL 41 45
BAGG HJ /
MAVOR JW 21 P SOC EXP BIOL MED 18 301
MAVOR JW 21 SCIENCE N S 54 347
MAVOR JW 23 GENETICS 8 545
MAVOR JW 24 GENETICS 9 70
SVENSON HK /
MCCLUNG CE 17 J MORPH 29 519
MORGAN LV 22 BIOL B 42 267
MORGAN LV 25 GENETICS 10 148
MORGAN TH 23 CARN I WASH YR BK ¤ 22 283
STURTEVANT AH /
BRIDGES CB /
MULLER HJ 25 IN PRESS ¤
PLOUGH HH 17 J EXP ZOOL 24 147
PLOUGH HH 21 J EXP ZOOL 32 187
STRANGEWAYS TSP 23 P ROY SOC LOND B 95 373
OAKLEY HEH /
STURTEVANT AH 23 SCIENCE 57 746
MORGAN TH /

NIRENBER.MW MATTHAEI JH
P N A S - 47 1588 61 57R 26B 0 40
U.S.A.CIT BY 0. CIT 1. CIT IND BY 0. CIT IND 5
THE DEPENDENCE OF CELL-FREE PROTEIN SYNTHESIS IN E COLI UPON NATURALLY OCCURRING OR SYNTHETIC POLYRIBONUCLEOTIDES¤¤USED POLYURIDYLIC ACID IN CELL FREE SYSTEM TO PRODUCE A PROTEIN COMPOSED ONLY OF PHENYLALANINE . THE FIRST STEP IN BREAKING THE GENETIC CODE

01100
#NAT I HEALTH
MATTHAEI JH
NIRENBERG MW / 61 P NATL ACAD SCI 47 1580
NIRENBERG MW
MATTHAEI JH / 61 BIOCHEM BIOPHYS RES 4 404
NIRENBERG MW
MATTHAEI JH / 61 FED P 20 391
NIRENBERG MW
CRESTFIELD AM / 55 J BIOL CHEM 216 185
SMITH KC
ALLEN FW / 59 J BIOL CHEM 234 1525
DAVIS FF
CARLUCCI AF / 59 J MOL BIOL 1 111
ROUBEIN IF
HALL BD / 60 BIOCHIM BIOPHYS ACTA 43 110
DOTY P
OSAWA S / 61 BIOPHYS J 1 215
ARONSON AI
MCCARTHY BJ / 60 J MOL BIOL 2 83
KURLAND CG / 59 BIOCHIM BIOPHYS ACTA 32 320
LITTAUER UZ
EISENBERG H / 60 P NATL ACAD SCI 46 1554
HOAGLAND MB
COMLY LT / 58 VIROLOGY 6 545
VOLKIN E
ASTRACHAN L / 60 J MOL BIOL 2 306
COUNTRYMAN JL / 60 J MOL BIOL 2 306
NOMURA M
HALL BD / 61 P NATL ACAD SCI 47 137
SPIEGELMAN S
HALL BD / 58 MICROS PART. PROT SYN¤ 18
SPIEGELMAN S
BOLTON ET / 59 J MOL BIOL 1 221
HOYEN BH
RITTER DB / 60 P NATL ACAD SCI 46 1450
ROBERTS RB
TISSIERES A / 61 BIOPHYS J 1 227
WATSON JD
SCHLESSINGER D / 54 J GEN PHYSIOL 38 145
HOLLINGWORTH BR / 56 CANAD J MICROBIOL 2 585
TISSIERES A
SCHLESSINGER D / 60 J MOL BIOL 2 153
GROS F
MCCARTHY BJ / 52 J BIOL CHEM 195 549
ARONSON AI / 60 SCIENCE 131 32
HERSHEY AD
SIMINOVITCH L / 61 J BIOL CHEM 236 1373
GRAHAM AF
DAVERN CI / 58 MICROS PART. PROT SYN¤ 322
MESELSON M
SIEKEVITZ P
BRITTEN RJ
ROBERTS RB
MARTIN R
AMES B
BANFORD CH
ELLIOTT A
HANBY WE

NIRENBER.MW MATTHAEI JH JONES OW
P N A S - 48 104 62 36R 13B C 40
U.S.A.CIT BY 0. CIT 1. CIT IND BY 0. CIT IND 5
AN INTERMEDIATE IN THE BIOSYNTHESIS OF POLYPHENYLALANINE DIRECTED BY SYNTHETIC TEMPLATE RNA¤¤USED POLYURIDYLIC ACID IN CELL FREE SYSTEM TO PRODUCE A PROTEIN COMPOSED ONLY OF PHENYLALANINE . FIRST STEP IN BREAKING THE GENETIC CODE

01100
#NAT I HEALTH
OCHOA S PERSONAL COMMUNICATI¤
FRAENKELCONRAT H PERSONAL COMMUNICATI¤
NIRENBERG MW / 61 S INT C BIOCH MOSC ¤
MATTHAEI JH
NIRENBERG MW / 61 P NATL ACAD SCI 47 1588
MATTHAEI JH
BELJANSKI M / 60 BIOCHIM BIOPHYS ACTA 41 104
VONEHRENSTEIN G / 61 P NATL ACAD SCI 47 941
LIPMANN F / 59 CARN I WASH YEARB ¤ 229
ARONSON AI
BOLTON ET
BRITTEN RJ
COWIE DB
DUERKSEN JD
MCCARTHY BJ
MCQUILLEN K
ROBERTS RB / 59 CR ACAD SCI PARIS 248 2036
NISHAN B
FUKUHARA H / 52 J BIOL CHEM 195 549
SIEKEVITZ P / 51 J BIOL CHEM 193 265
LOWRY OH
ROSEBROUGH NJ
FARR AL
RANDALL RJ / 61 P NATL ACAD SCI 47 497
NATHANS D / 59 P NATL ACAD SCI 45 505
LIPMANN F
HECHT L
STEPHENSON ML / 56 J AM CHEM SOC 78 3548
ZAMECNIK PC / 57 BIOCHIM BIOPHYS ACTA 26 497
RICH A
DAVIES DR / 61 P NATL ACAD SCI 47 1149
FELSENFELD G
RICH A
BENZER S
WEISBLUM B

NIRENBER.MW SEE MATTHAEI JH P N A S - 47 1588

NOVELLI GD EISENSTA.JM KAMEYAMA T
SCIENCE -L 133 1369 61 3R 1B A 38
U.S.A.CIT BY 0. CIT 2. CIT IND BY 0. CIT IND 1
A REQUIREMENT FOR GENETICALLY SPECIFIC DNA IN THE CELL-FREE SYNTHESIS OF THE ENZYME BETA-GALACTOSIDASE¤¤MANUFACTURED MESSENGER RNA FROM CELL FRAGMENTS AND USED IT AS A MODEL IN THE FORMATION OF BETA-GALACTOSIDASE

01010
#OAKRIDGE NAT LAB
KAMEYAMA T / 60 BIOCHEM BIOPHYS RES 2 393
NOVELLI GD /

NOVELLI GD SEE EISENSTA.JM P N A S - 48 652
NOVELLI GD SEE KAMEYAMA T P N A S - 48 659

OCHOA S
FED PROC - 15 832 56 100R 42B C 32
U.S.A.CIT BY 1. CIT 3. CIT IND BY 4. CIT IND 2
ENZYMATIC SYNTHESIS OF RIBONUCLEIC ACID-LIKE POLYNUCLEOTIDES¤¤ENZYMATIC SYNTHESIS OF RNA

11000
#NYU COLLEGE MED
PUB HEALTH SERV
NAT I ART MET DIS
AMER CANCER SOC
ROCKEF F
OFFICE NAVAL RES
GRUNBERGMANAGO M / 55 J AM CHEM SOC 77 3165
OCHOA S
GRUNBERGMANAGO M / 55 SCIENCE 122 907
ORTIZ PJ
OCHOA S
GRUNBERGMANAGO M / 56 BIOCHIM BIOPHYS ACTA 20 269
ORTIZ PJ
OCHOA S
BRUMMOND DO / 56 FED P 15 225
OCHOA S
POTTER VR / 55 CANADIAN CANCER C ¤ 1 290
BEGG RW
SCHMITZ H / 54 J BIOL CHEM 209 41
HURLBERT RB
POTTER VR
STROMINGER JL / 54 ARCH BIOCHEM 52 488
HEPPEL LA
MAXWELL ES
STROMINGER JL / 55 FED P 14 288
HEPPEL LA
MAXWELL ES
HEPPEL LA / 56 FED P 15 273
SMITH JD
ORTIZ PJ
OCHOA S
HURST RO / 51 J BIOL CHEM 193 91
BUTLER GC
BUTLER GC / 55 METHODS ENZYMOLOGY ¤ 2 561
COLOWICK
KAPLAN
HEPPEL LA / 55 METHODS ENZYMOLOGY ¤ 2 565
HILMOE RJ
COLOWICK
KAPLAN
COHN WE / 52 PHOSPHORUS METAB ¤ 2 339
DOHERTY DG
VOLKIN E
MCELROY
GLASS
BROWN DM / 55 NUCLEIC ACIDS ¤ 1 409
TODD AR
CHARGAFF
DAVIDSON
MARKHAM R / 52 BIOCHEM J 52 552
SMITH JD
MARKHAM R / 54 NATURE 173 537
MATTHEWS REF
SMITH JD
PALADINI AC / 52 BIOCHEM J 151 426
LELOIR LF
MARKHAM R / 52 BIOCHEM J 52 558
SMITH JD
ZAMENHOF S / 52 PHOSPHORUS METAB ¤ 2 301
MCELROY
GLASS
SMELLIE RMS UNPUBLISHED EXPERIME¤
RICH A / 54 P NAT ACAD SC 40 759
WATSON JD
RICH A UNPUBLISHED EXPERIME¤
CAVALIERI LF UNPUBLISHED EXPERIME¤
ROSOFF M
WARNER RC / 56 FED P 15 379
WATSON JD / 53 NATURE 171 737
CRICK FHC
MARKHAM R / 52 BIOCHEM J 52 565
SMITH JD
GRUNBERGMANAGO M PERSONAL COMMUNICATI¤
GOLDWASSER E / 55 J AM CHEM SOC 77 6083
POTTER VR PERSONAL COMMUNICATI¤
MERRIFIELD RB / 52 J BIOL CHEM 197 521
WOOLLEY DW
MAGASANIK B / 55 NUCLEIC ACIDS ¤ 1 373
CHARGAFF
DAVIDSON
FRAENKELCONRAT H / 56 J AM CHEM SOC 78 882
HOTCHKISS R / 55 HARVEY LECTURES 49 134
SABLE HZ / 54 BIOCHIM BIOPHYS ACTA 13 156
WILBER PB
CORER AE
KANE MR
HECHT LI / 54 BIOCHIM BIOPHYS ACTA 15 134
POTTER VR
HERBERT E
POTTER RL / 55 J AM CHEM SOC 77 6714
SCHLESINGER S
KANAZIR D / 54 BIOCHIM BIOPHYS ACTA 13 589
KANAZIR D / 54 BIOCHIM BIOPHYS ACTA 12 293
KANAZIR D / 55 BIOCHIM BIOPHYS ACTA 16 477
ERRERA M
KORNBERG A / 56 FED P 15 291
LEHMAN IR
SIMMS ES
PRICE TD IN PRESS ¤
HUDSON PB
HINDS MM
DARMSTADT RA
ZAMENHOF S

BRUMMOND DO — UNPUBLISHED EXPER ¤
SMELLIE RMS /

OCHOA S — SEE GRUNBERG.M — J A C S -L 77 3165
OCHOA S — SEE GRUNBERG.M — SCIENCE - 122 907
ORTIZ PJ — SEE GRUNBERG.M — SCIENCE - 122 907

PALADE GE SIEKEVIT.P
J B B CYT- 2 171 56 153R 718 B 30
U.S.A.CIT BY 0. CIT 1. CIT IND BY 1. CIT IND 0
LIVER MICROSOMES - AN INTEGRATED MORPHOLOGICAL AND BIOCHEMICAL STUDY¤¤ISOLATION OF RNA CONTAINING RIBOSOMES

00110
*ROCKEF I MED RES

PALADE GE		55	FED P	14	262
SIEKEVITZ P	/				
CLAUDE A		41	COLD SPR HARBOR S QU	9	263
CLAUDE A		46	J EXP MED	84	51
CLAUDE A		43	SCIENCE	97	451
CLAUDE A		47	HARVEY LECTURES	48	121
BARNUM CP		48	ARCH BIOCHEM	19	17
HUSEBY RA	/				
SCHNEIDER WC		51	CANCER RESEARCH	11	1
HOGEBOOM GH	/				
HOGEBOOM GH		55	NUCLEIC ACIDS ¤	2	
SCHNEIDER WC	/				
CHARGAFF E	/				
DAVIDSON JN	/				
CLAUDE A		43	FRONT CYTOCHEM BIOL ¤	10	
BRENNER S		47	S AFR J MED SC	12	53
CHANTRENNE H		47	BIOCHIM BIOPHYSIC AC	1	437
PETERMANN ML		52	CANCER RESEARCH	12	373
HAMILTON MG	/				
PETERMANN ML		53	CANCER RESEARCH	13	372
MIZEN NA	/				
HAMILTON MG	/				
PETERMANN ML		54	CANCER RESEARCH	14	360
HAMILTON MG	/				
MIZEN NA	/				
BORSOOK H		50	FED P	9	154
DEASY CL	/				
HAAGENSMIT AJ	/				
KEIGHLEY G	/				
LOWY PH	/				
HULTIN T		50	EXP CELL RESEARCH	1	376
HULTIN T		50	EXP CELL RESEARCH	1	599
KELLER EB		51	FED P	10	206
LEE ND		51	J BIOL CHEM	192	733
ANDERSON JT	/				
MILLER R	/				
WILLIAMS RH	/				
TYNER EP		53	CANCER RESEARCH	13	186
HEIDELBERGER C	/				
LEPAGE GA	/				
SMELLIE RMS		53	BIOCHIM BIOPHYSIC AC	11	559
MCINDOE WM	/				
DAVIDSON JN	/				
SIEKEVITZ P		52	J BIOL CHEM	195	549
ALLFREY V		53	J GEN PHYSIOL	37	157
DALY MM	/				
MIRSKY AE	/				
ZAMECNIK PC		54	J BIOL CHEM	209	337
KELLER EB	/				
PORTER KR		53	J EXP MED	97	727
PALADE GE		54	J EXP MED	100	641
PORTER KR	/				
PALADE GE		55	J BIOPHYSIC BIOCHEM	1	59
PALADE GE		55	J BIOPHYSIC BIOCHEM	1	567
HOGEBOOM GH		48	J BIOL CHEM	172	619
SCHNEIDER WC	/				
PALADE GE	/				
STRITTMATTER CF		52	P NAT ACAD SC	38	19
BALL EG	/				
STRITTMATTER CF		54	J CELL COMP PHYSIOL	43	57
BALL EG	/				
HOGEBOOM GH		49	J BIOL CHEM	177	847
PALADE GE		51	ARCH BIOCHEM	30	144
LAIRD AK		53	EXP CELL RESEARCH	5	147
NYGAARD O	/				
RIS H	/				
BARTON AQ	/				
PICKELS EG		43	J GEN PHYSIOL	26	341
SCHNEIDER WC		45	J BIOL CHEM	161	293
MEJBAUM W		39	Z PHYSIOL CHEM	258	117
FISKE CH		25	J BIOL CHEM	66	375
SUBBAROW Y	/				
UMBREIT WW		46	MANOMETRIC TECHNIQUE¤		
BURRIS RH	/				
STAUFFER JF	/				
PALADE GE		52	J EXP MED	95	285
PALADE GE		52	IN PRESS ¤		
NEWMAN SB		49	J RESEARCH NAT BUR S	43	183
BORYSKO E	/				
SWERDLOW M	/				
PORTER KR		53	ANAT REC	117	685
BLUM J	/				
PALAY SL		55	BIOPHYSIC BIOCHEM CY	1	69
PALADE GE	/				
DALTON AJ		54	AM J ANAT	94	171
FELIX MC	/				
SJOSTRAND FS		54	EXP CELL RESEARCH	7	415
HANZON V	/				
RHODIN J		54	CORR ULTR ORG FUNCT ¤		
FAWCETT DW		55	J NAT CANCER I SS	15	1475
SCHNEIDER WC		48	J BIOL CHEM	176	259
SCHNEIDER WC		50	J NAT CANCER I	10	977
HOGEBOOM GH	/				
ROSS ME	/				
KRETCHMER N		51	ARCH BIOCHEM BIOPHYS	31	141
BARNUM CP	/				
AVERY OT		44	J EXP MED	79	137
MACLEOD CM	/				
MCCARTY M	/				
EICHEL B		50	J BIOL CHEM	183	89
WAINO WW	/				
PFRSON P	/				
COOPERSTEIN SJ	/				
BEAUFAY H		54	B SOC CHIM BIOL	36	1551
DEDUVE C	/				
SCHMIDT G		51	J BIOL CHEM	192	715
CUBILES R	/				
ZOLLNER N	/				
HECHT L	/				
STRICKLER N	/				
SERAIDARIAN K	/				
SERAIDARIAN M	/				
THANNHAUSER SJ	/				
HOGEBOOM GH		53	CANCER RESEARCH	13	617
SCHNEIDER WC	/				
STRIEBICH MJ	/				
GREEN DE		52	J CELL COMP PHYSIO S	39	2
GREEN DE		52	J CELL COMP PHYSIO S	39	75
ABOOD LG		55	EXP CELL RESEARCH	8	459
ROMANCHEK L	/				
HOGEBOOM GH		55	FED P	14	633
BERNHARD W		54	ARCH ANAT MICR MORPH	43	236
GAUTIER A	/				
ROUILLER C	/				
SLAUTTERBACK DB		53	EXP CELL RESEARCH	5	173
CHAUVEAU J		51	ARCH SC PHYSIOL	5	277
CLEMENT G	/				
HOWATSON AF		53	BRIT J CANCER	7	393
SMELLIE RMS		53	BIOCHEM J	54	280
MCINDOE WM	/				
LOGAN R	/				
DAVIDSON JN	/				
BOROWAEYS J		46	COMPT REND SOC BIOL	140	136
DERVICHIAN D	/				
TSUBOI KK		54	EXP CELL RESEARCH	7	32
DETERRA N	/				
HEIDSON PB	/				
LITTLEFIELD JW		55	J BIOL CHEM	217	111
KELLER EB	/				
GROSS J	/				
ZAMECNIK PC	/				
NOVIKOFF AB		54	J HISTOCHEM CYTOCHEM	2	401
RYAN J	/				
PODBER E	/				
PETERMANN ML		55	J BIOPHYSIC BIOCHEM	1	469
HAMILTON MG	/				
BRACHET J		55	NUCLEIC ACIDS ¤	2	
CHARGAFF E	/				
DAVIDSON JN	/				
KUFF		56	J BIOPHYSIC BIOCHEM	2	33
HOGEBOOM GH	/				
DALTON	/				

PALADE GE PORTER KR
J EX MED - 100 641 54 50R 298 A 30
U.S.A.CIT BY 0. CIT 1. CIT IND BY 1. CIT IND 0
STUDIES ON THE ENDOPLASMIC RETICULUM .1. ITS IDENTIFICATION IN CELLS IN SITU¤¤DISCOVERY OF MICROSOMES IN THE ENDOPLASMIC RETICULUM

00110
*ROCKEF I MED RES

PALADE GE		52	ANAT REC	112	370
PORTER KR	/				
PORTER KR		45	J EXP MED	81	233
CLAUDE A	/				
FULLAM EF	/				
PORTER KR		47	CANCER RESEARCH	7	431
THOMPSON HP	/				
PORTER KR		48	J EXP MED	88	15
THOMPSON HP	/				
PORTER KR		52	ANN NEW YORK ACAD SC	54	882
KALLMAN FL	/				
PORTER KR		53	J EXP MED	97	727
OBERLING C		50	B ASS F ETUDE CANCER	37	97
BERNHARD W	/				
GUERIN M	/				
HARREL J	/				
MARTIN A		50	BIOCHIM BIOPHYS ACTA	5	154
TOMLIN SG	/				
SELBY CC		52	CANCER	5	770
BERGER RE	/				
PALADE GE		52	J EXP MED	95	285
NEWMAN SB		49	J RES NAT BUR STAND	43	183
BORYSKO E	/				
SWERDLOW M	/				
PORTER KR		53	ANAT REC	117	685
BLUM J	/				
WATSON ML		52	UR185 U ROCH AT EN ¤		
SJOSTRAND FS		53	NATURE	171	30
BRADFIELD JRG		53	QUART J MICRO SC	94	353
PORTER KR		53	EXP CELL RESEARCH	4	127
KALLMAN FL	/				
FAWCETT DW		52	J LAB CLIN MED	39	354
VALLEE BL	/				
WEISS L		53	J HISTOCHEM CYTOCHEM	1	47
FAWCETT DW	/				
CARREL A		26	J EXP MED	44	285
EBELING AH	/				
METHERINGTON DC		31	ARCH EXP ZELLFORSCH	12	1
PIERCE EJ	/				
LEWIS MR		25	AM J PATH	1	91
MAXIMOW AA		28	ARCH EXP ZELLFORSCH	5	166
BLOOM W		28	ARCH EXP ZELLFORSCH	5	269
PALADE GE		53	J APPL PHYSICS	24	1419
PALADE GE		52	ANAT REC	114	427
PALADE GE		55	J HISTOCHEM CYTOCHEM	1	188
BORYSKO E		53	B JOHNS HOPKINS HOSP	92	257
BANG FB	/				
PORTER KR		53	J APPL PHYSICS	24	1424
PALADE GE		53	J APPL PHYSICS	24	1424

PAULING L COREY RB
J A C S -L 72 5349 50 2R 18 A 23
U.S.A.CIT BY 0. CIT 0. CIT IND BY 1. CIT IND 0
2 HYDROGEN-BONDED SPIRAL CONFIGURATIONS OF THE POLYPEPTIDE CHAIN¤¤DEMONSTRATED HELICAL BENDING OF POLYPEPTIDES AND H BONDING BETWEEN HELIXES

00010
*CAL I TECH
ROCKEF F
NAT F INF PARALYS

HUGGINS ML		43	CHEM REV	32	211

PAULING L COREY RB BRANSON HR
P N A S - 37 205 51 22R 108 B 23
U.S.A.CIT BY 0. CIT 0. CIT IND BY 1. CIT IND 0
THE STRUCTURE OF PROTEINS - 2 HYDROGEN-BONDED HELICAL CONFIGURATIONS OF THE POLYPEPTIDE CHAIN¤¤DEMONSTRATED HELICAL BENDING OF POLYPEPTIDES AND H BONDING BETWEEN HELIXES

00010
*CAL I TECH

ROCKEF F
NAT F INF PARALYS
PUB HEALTH SERV

PAULING L — 50 J AM CHEM SOC — 72 5349
COREY RB /
COREY RB — 50 J AM CHEM SOC — 72 2899
DONOHUE J /
LEVY HA — 41 J AM CHEM SOC — 63 2095
COREY RB /
DONOHUE J — 50 J AM CHEM SOC — 72 949
SHOEMAKER DP — 50 J AM CHEM SOC — 72 2328
DONOHUE J /
SCHOMAKER V /
COREY RB /
CARPENTER GB — 50 J AM CHEM SOC — 72 2315
DONOHUE J /
HUGHES EW — 49 J AM CHEM SOC — 71 2618
MOORE WJ /
ASTBURY WT — 41 NATURE — 147 696
BELL FO /
HUGGINS ML — 43 CHEM REV — 32 195
BRAGG L — 50 P ROY SOC — A203 321
KENDREW JC /
PERUTZ MF /

PAULING L COREY RB
P N A S 37 235 51 11R 4B C 23
U.S.A.CIT BY 0. CIT 0. CIT IND BY 1. CIT IND 0
ATOMIC COORDINATES AND STRUCTURE FACTORS FOR 2
HELICAL CONFIGURATIONS OF POLYPEPTIDE
CHAINS==DEMONSTRATED HELICAL BENDING OF
POLYPEPTIDES AND H BONDING BETWEEN HELIXES

C0010
*CAL I TECH
ROCKEF F
NAT F INF PARALYS
PUB HEALTH SERV

PAULING L — 50 J AM CHEM SOC — 72 5349
COREY RB /
PAULING L — 51 P NATL ACAD SCI — 37 205
COREY RB /
BRANSON HR /
PAULING L — 51 P NATL ACAD SCI — 37 241
COREY RB /
BAMFORD CH — 51 P ROY SOC — A205 30
HANBY WE /
HAPPEY F /

PILOTY O — SEE FISCHER E — BER DTSCH- — 24 4214
PIRIE NW — SEE BAWDEN FC — NATURE -A — 138 1051
PIRIE NW — SEE BAWDEN FC — P RS BIOL- — 123 274
POPENOE EA — SEE DUVIGNEA.V — J A C S -L — 75 4880
PORTER KR — SEE PALADE GE — J EX MED - — 100 641
RANDALL JT — SEE WILKINS MHF — B B ACTA -L — 10 192
RESSLER C — SEE DUVIGNEA.V — J A C S -L — 75 4879
ROBERTS CW — SEE DUVIGNEA.V — J A C S -L — 75 4879

SANGER F TUPPY H
BIOCHEM J- 49 463 51 44R 24B B 24
GR.BR.CIT BY 0. CIT 1. CIT IND BY 2. CIT IND 0
THE AMINO-ACID SEQUENCE IN THE PHENYLALANYL
CHAIN OF INSULIN .1. THE IDENTIFICATION OF
LOWER PEPTIDES FROM PARTIAL
HYDROLYSATES==DETERMINATION OF THE AMINO ACID
SEQUENCE OF INSULIN

00111
*U CAMBRIDGE
MED RES COUN BR

BRAND E — 47 ANN REV BIOCHEM — 16 224
EDSALL JT /
CONSDEN R — 44 BIOCHEM J — 38 224
GORDON AH /
MARTIN AJP /
CONSDEN R — 47 BIOCHEM J — 41 590
GORDON AH /
MARTIN AJP /
CONSDEN R — 48 BIOCHEM J — 42 443
GORDON AH /
MARTIN AJP /
CONSDEN R — 49 BIOCHEM J — 44 548
GORDON AH /
MARTIN AJP /
CONSDEN R — 47 BIOCHEM J — 41 596
GORDON AH /
MARTIN AJP /
SYNGE RLM /
DENT CE — 47 BIOCHEM J — 41 240
DENT CE — 48 BIOCHEM J — 43 169
DESNUELLE P — 48 BIOCHIM BIOPHYS ACTA — 2 64
CASAL A /
JONES TSG — 49 DISCUSS FARADAY SOC — 7 285
MACPHERSON HT — 46 BIOCHEM J — 40 670
PARTRIDGE SM — 48 BIOCHEM J — 42 238
PARTRIDGE SM — 50 NATURE LOND — 165 62
DAVIS HF /
PHILLIPS DMP — 48 NATURE LOND — 161 53
SANGER F — 49 BIOCHEM J — 44 126
SANGER F — 48 BIOCHEM J — 45 563
SANGER F — 49 COLD SPR HARB S QUAN — 14 153
SANGER F — 51 BIOCHEM J — 49 481
TUPPY H /
SYNGE RLM — 43 CHEM REV — 32 139
SYNGE RLM — 51 IN THE PRESS — B
THEORELL H — 42 ARK KEMI ATA GEOL — A 16
AKESON A /
TISELIUS A — 47 EXPERIENTIA — 3 651
DRAKE B /
HAGDAHL L /
TRISTRAM GR — 49 ADVANC PROT CHEM — 5 83
WIELAND T — 49 BER DTSCH CHEM GES — 82 468
WIRTH L /

SANGER F TUPPY H
BIOCHEM J- 49 491 51 31R 10B A 24
GR.BR.CIT BY 0. CIT 1. CIT IND BY 2. CIT IND 0
THE AMINO-ACID SEQUENCE IN THE PHENYLALANYL
CHAIN OF INSULIN .2. THE INVESTIGATION OF
PEPTIDES FROM ENZYMIC HYDROLYSATES==DETERMINAT
ION OF THE AMINO ACID SEQUENCE OF INSULIN

00111
*U CAMBRIDGE
MED RES COUN BR

BERGMANN M — 37 J BIOL CHEM — 118 405
FRUTON JS /

BERGMANN M — 39 J BIOL CHEM — 127 643
FRUTON JS /
POLLOK H /
CHIBNALL AC — 51 BIOCHEM J — 48 R 47
REES MW /
DESNUELLE P — 50 BIOCHIM BIOPHYS ACTA — 5 116
ROVERY M /
BONJOUR G /
FROMAGEOT C — 50 BIOCHIM BIOPHYS ACTA — 6 283
JUTISZ M /
MEYER D /
PENASSE L /
FRUTON JS — 39 J BIOL CHEM — 127 627
BERGMANN M /
HARINGTON CR — 44 NATURE LOND — 154 301
PITTRIVERS R /
HOFMANN K — 39 J BIOL CHEM — 130 81
BERGMANN M /
KUNITZ M — 36 J GEN PHYSIOL — 19 991
NORTHROP JH /
LENS J — 49 BIOCHIM BIOPHYS ACTA — 3 367
MARTIN AJP — 49 BIOCHEM SOC S — 3 4
REES MW — 46 BIOCHEM J — 40 632
SANGER F — 45 BIOCHEM J — 39 507
SANGER F — 49 BIOCHEM J — 44 126
SANGER F — 49 BIOCHEM J — 45 563
SANGER F — 51 BIOCHEM J — 49 463
TUPPY H /

SANGER F THOMPSON EO
BIOCHEM J- 53 353 53 38R 19B C 24
GR.BR.CIT BY 0. CIT 1. CIT IND BY 2. CIT IND 0
THE AMINO-ACID SEQUENCE IN THE GLYCYL CHAIN OF
INSULIN .1. THE IDENTIFICATION OF LOWER
PEPTIDES FROM PARTIAL HYDROLYSATES==DETERMINAT
ION OF THE AMINO ACID SEQUENCE OF INSULIN

00111
*U CAMBRIDGE

ANDREWS S — 27 J BIOL CHEM — 73 651
SCHMIDT CLA /
BISERTE G — 51 B SOC CHIM BIOL PARI — 33 50
OSTEAUX R /
BLACKBURN S — 51 BIOCHEM J — 48 126
LOWTHER AG /
CHIBNALL AC — 51 BIOCHEM J — 48 R 47
REES MW /
CONSDEN R — 50 BIOCHEM J — 46 8
GORDON AH /
CONSDEN R — 46 BIOCHEM J — 40 33
GORDON AH /
MARTIN AJP /
CONSDEN R — 47 BIOCHEM J — 41 590
GORDON AH /
MARTIN AJP /
CONSDEN R — 48 BIOCHEM J — 42 443
GORDON AH /
MARTIN AJP /
CONSDEN R — 49 BIOCHEM J — 44 548
GORDON AH /
MARTIN AJP /
DURRUM EL — 50 J AMER CHEM SOC — 72 2943
GUTFREUND H — 49 BIOCHEM J — 44 163
OGSTON AG /
KRITCHEVSKY TH — 51 SCIENCE — 114 299
TISELIUS A /
MONNIER R — 50 CR ACAD SCI PARIS — 230 1176
PENASSE L /
SANGER F — 49 BIOCHEM J — 44 126
SANGER F — 49 BIOCHEM J — 45 563
SANGER F — 51 BIOCHEM J — 49 463
TUPPY H /
SANGER F — 51 BIOCHEM J — 49 481
TUPPY H /
TRISTRAM GR — 49 ADVANC PROTEIN CHEM — 5 83
WOOLLEY DW — 48 FED P — 7 200

SANGER F THOMPSON EO
BIOCHEM J- 53 366 53 38R 17B D 24
GR.BR.CIT BY 0. CIT 1. CIT IND BY 2. CIT IND 0
THE AMINO-ACID SEQUENCE IN THE GLYCYL CHAIN OF
INSULIN .2. THE INVESTIGATION OF PEPTIDES FROM
ENZYMIC HYDROLYSATES==DETERMINATION OF THE
AMINO ACID SEQUENCE OF INSULIN

00111
*U CAMBRIDGE

BUTLER JAV — 50 BIOCHEM J — 46 74
PHILLIPS DMP /
STEPHEN JML /
CREETH JM /
CHIBNALL AC — 51 BIOCHEM J — 48 R 47
REES MW /
CHIBNALL AC — 52 BIOCHEM J — 52 R 3
REES MW /
DURRUM EL — 50 J AMER CHEM SOC — 72 2943
FROMAGEOT C — 50 BIOCHIM BIOPHYS ACTA — 6 283
JUTISZ M /
MEYER D /
PENASSE L /
FRUTON JS — 39 J BIOL CHEM — 127 627
BERGMANN M /
HARRIS JI — 52 J AMER CHEM SOC — 74 2944
HUGHES WRL — CITED INDIRECTLY — B
HERRIOT RM — 47 ADVANC PROTEIN CHEM — 3 169
JANSEN EF — 49 J BIOL CHEM — 179 189
NUTTING MD /
JANG R /
BALLS AK /
LENS J — 49 BIOCHIM BIOPHYS ACTA — 3 367
MELVILLE J — 35 BIOCHEM J — 29 179
POLSON A — 47 SCIENCE — 105 603
MOSLEY VM /
WYCKOFF RWG /
SANGER F — 53 BIOCHEM J — 53 353
THOMPSON EOP /
SANGER F — 53 UNPUBLISHED — B
THOMPSON EOP /
SANGER F — 51 BIOCHEM J — 49 463
TUPPY H /
SANGER F — 51 BIOCHEM J — 49 481
TUPPY H /
THOMPSON AR — 52 NATURE LOND — 169 495
PARTRIDGE SM /

SCHULTZ J SEE CASPERSS-T NATURE -L 142 204
SCHULTZ J SEE CASPERSS-T NATURE -L 143 602
SCOTT JF SEE HOAGLAND MB J B C - 231 241

SIBATANI A DEKLOET SR ALLFREY VG MIRSKY AE
P N A S - 48 471 62 73R 218 39
U.S.A.CIT BY 0. CIT 2. CIT IND BY 0. CIT IND 1
ISOLATION OF A NUCLEAR RNA FRACTION RESEMBLING DNA IN ITS BASE COMPOSITION¤¤ISOLATION OF MESS ENGER RNA FROM ANIMAL CELLS

01010
*ROCKEF I MED RES
PUB HEALTH SERV
VOLKIN E 56 VIROLOGY 2 149
ASTRACHAN L /
NOMURA M 60 J MOL BIOL 2 306
HALL BD /
SPIEGELMAN S /
BRENNER S 61 NATURE 190 576
JACOB F /
MESELSON M /
JACOB F 61 J MOL BIOL 3 318
MONOD J /
GROS F 61 PROTEIN BIOSYNTHESIS¤ 195
NAONO S /
HARRIS RJC /
ALLFREY VG 57 P NAT ACAD SCI 43 821
MIRSKY AE /
SIBATANI A 60 NATURE 186 215
KIMURA K /
YAMANA K /
TAKAHASHI T /
YAMANA K 60 BIOCHIM BIOPHYS ACTA 41 295
SIBATANI A /
GEORGIEV GP 60 BIOKHIMIYA 25 143
MANTIEVA VL /
GEORGIEV GP 61 BIOCHIM BIOPHYS ACTA 46 399
SAMARINA OP /
MANTIEVA VL /
ZBARSKY IB /
KIMURA K IN PRESS ¤
NAORA H UNPUBLISHED EXPERIME¤
NAORA H /
MIRSKY AE /
ALLFREY VG 57 J GEN PHYSIOL 40 451
MIRSKY AE /
OSAWA S /
ALLFREY VG 61 PROTEIN BIOSYNTHESIS¤ 49
MIRSKY AE /
HARRIS RJC /
ALLFREY VG 59 P NAT ACAD SCI 45 1325
MIRSKY AE /
HOPKINS JW 59 P NAT ACAD SCI 45 1461
ALLFREY VG 60 ANN NY ACAD SCI 88 722
HOPKINS JW /
FRENSTER JH /
MIRSKY AE /
FRENSTER JH 60 P NAT ACAD SCI 46 432
ALLFREY VG /
MIRSKY AE /
POGO AO IN PRESS ¤
POGO BGT /
LITTAU VC /
ALLFREY VG /
MIRSKY AE /
HAMILTON MG /
KIRBY KS 57 BIOCHEM J 66 495
DISCHE Z 57 BIOCHIM BIOPHYS ACTA 23 639
BORENFREUND E /
BURTON K 56 BIOCHEM J 62 315
DISCHE Z 30 MIKROCHEMIE 6 4
SMITH JD 50 BIOCHEM J 46 509
MARKHAM R /
HURLBERT RB 54 J BIOL CHEM 209 23
SCHMITZ H /
BRUMM AE /
POTTER VR /
ALLEN RJL 40 BIOCHEM J 34 858
HOAGLAND MB 60 NUCLEIC ACIDS ¤ 3 360
CHARGAFF E /
DAVIDSON JN /
WEISS SB 60 P NAT ACAD SCI 46 1020
HURWITZ J 60 BIOCHEM BIOPHYS RES 3 15
BRESLER A /
DIRINGER R /

SIEKEVIT-P SEE PALADE GE J B B CYT- 2 171
SIMMS ES SEE KORNBERG A B B ACTA -L 21 197
SIMMS ES SEE KORNBERG A FED PROC -M 15 291

STANLEY WM
SCIENCE -L 81 644 35 6R 38 14
U.S.A.CIT BY 1. CIT 0. CIT IND BY 2. CIT IND 0
ISOLATION OF A CRYSTALLINE PROTEIN POSSESSING THE PROPERTIES OF TOBACCO-MOSAIC VIRUS¤¤ISOLATION OF TOBACCO-MOSAIC VIRUS

01000
*ROCKEF I MED RES
VINSON CG 31 CONTRIB BUYCE THOMPS 3 131
PETRE AW /
BARTONWRIGHT E 39 NATURE 132 1003
MCBAIN A /
CALDWELL J 34 NATURE 133 177

STEPHENS-ML SEE HOAGLAND MB B B ACTA -L 24 215
STEPHENS-ML SEE HOAGLAND MB J B C - 231 241
STOKES AR SEE WILKINS MHF NATURE - 171 738
SWAN JM SEE DUVIGNEAUD V J A C S -L 75 4879
SYNGE RLM SEE GORDON AH BIOCHEM J-M 37 R 13
TATUM EL SEE BEADLE GW P N A S - 27 499
THOMPSON EO SEE SANGER F BIOCHEM J- 53 353
THOMPSON EO SEE SANGER F BIOCHEM J- 53 366
TISDALE WS SEE LEVENE PA J B C - 109 413
TODD AR SEE MICHELSON-AM- J CHEM S - 2633
TUPPY H SEE SANGER F BIOCHEM J- 49 481
TUPPY H SEE SANGER F BIOCHEM J- 49 481

WATSON JD CRICK FHC
NATURE - 171 737 53 13R 78 A 27
GR.BR.CIT BY 1. CIT 1. CIT IND BY 0. CIT IND 2
MOLECULAR STRUCTURE OF NUCLEIC ACIDS - A STRUCTURE FOR DEOXYRIBOSE NUCLEIC ACID¤¤DETERMINED THE DOUBLE HELIX STRUCTURE OF DNA WHICH DEMONSTRATED ITS POTENTIAL FOR REPLICATION

01100
*U CAMBRIDGE
PAULING L 53 NATURE 171 346
COREY RB /
PAULING L 53 P US NAT ACAD SCI 39 84
COREY RB /
FURBERG S 52 ACTA CHEM SCAND 6 634
ZAMENHOF S 52 BIOCHIM BIOPHYS ACTA 9 402
BRAWERMAN G /
CHARGAFF E /
WYATT GR 52 J GEN PHYSIOL 36 201
ASTBURY WT 47 1 S SOC EXP BIOL ¤ 66
WILKINS MHF 53 BIOCHIM BIOPHYS ACTA 10 192
RANDALL JT /

WATSON JD CRICK FHC
NATURE - 171 964 53 21R 118 B 27
GR.BR.CIT BY 1. CIT 1. CIT IND BY 0. CIT IND 2
GENETICAL IMPLICATIONS OF THE STRUCTURE OF DEOXYRIBONUCLEIC ACID¤¤DETERMINED THE DOUBLE HELIX STRUCTURE OF DNA WHICH DEMONSTRATED ITS POTENTIAL FOR REPLICATION

01100
*U CAMBRIDGE
WATSON JD 53 NATURE 171 737
CRICK FHC /
WILKINS MHF 53 NATURE 171 738
STOKES AR /
WILSON HR /
FRANKLIN RE 53 NATURE 171 740
GOSLING RG /
ASTBURY WT 47 1 S SOC EXP BIOL ¤ 66
FURBERG S 52 ACTA CHEM SCAND 6 634
PAULING L 53 NATURE 171 346
COREY RB /
PAULING L 53 P US NAT ACAD SCI 39 84
COREY RB /
FRASER RDB IN PREPARATION ¤
WILKINS MHF 53 BIOCHIM BIOPHYS ACTA 10 192
RANDALL JT /
ZAMENHOF S 52 BIOCHIM BIOPHYS ACTA 9 402
BRAWERMAN G /
CHARGAFF E /
WYATT GR 52 J GEN PHYSIOL 36 201

WILKINS MHF RANDALL JT
B B ACTA -L 10 192 53 6R 48 A 26
GR.BR.CIT BY 1. CIT 0. CIT IND BY 0. CIT IND 0
CRYSTALLINITY IN SPERM HEADS - MOLECULAR STRUCTURE OF NUCLEOPROTEIN IN VIVO¤¤STUDIED NUCLEIC ACID STRUCTURE BY X-RAY DIFFRACTION

00100
*KINGS COLLEGE
SCHMIDT WJ 37 DOPPELBRECHUNG KARYO¤
WILKINS MHF 51 PUB STAZ ZOOL N S104 23
RINNE F 33 T FARADAY SOC 29 1016
WILKINS MHF IN PREPARATION ¤
BATTAGLIA /

WILKINS MHF STOKES AR WILSON HR
NATURE - 171 738 53 14R 68 B 26
GR.BR.CIT BY 1. CIT 0. CIT IND BY 0. CIT IND 0
MOLECULAR STRUCTURE OF DEOXYPENTOSE NUCLEIC ACIDS¤¤STUDIED NUCLEIC ACID STRUCTURE BY X-RAY DIFFRACTION

00100
*KINGS COLLEGE
ASTBURY WT 47 1 S SOC EXP BIOL ¤
RILEY DP 51 BIOCHIM BIOPHYS ACTA 7 526
OSTER G /
WILKINS MHF 51 NATURE 167 759
GOSLING RG /
SEEDS WE /
ASTBURY WT 38 COLD SPRING HARB S Q 6 109
BELL FO /
COCHRAN W 52 ACTA CRYST 5 581
CRICK FHC /
VAND V /
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RANDALL JT /

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WILLIAMS RC SEE FRAENKEL-M P N A S - 41 690
WILSON HR SEE WILKINS MHF NATURE - 171 738
ZAMECNIK PC SEE HOAGLAND MB B B ACTA -L 24 215
ZAMECNIK PC SEE HOAGLAND MB J B C - 231 241

APPENDIX VII

LEGEND FOR THE NETWORK CHARTS

ASIMOV'S CONNECTIONS
RED OVERLAYS 1 & 2

First overlay (red) – Asimov's specified historical connections -- solid lines.
Second overlay (red) – Asimov's implied historical connections -- broken lines.

COINCIDENT CITATION CONNECTIONS
BLUE OVERLAYS 3 & 4

Third overlay (blue) – Coincident strong citation connections -- strong citation connections which *coincide* with Asimov's historical connections, specified and/or implied.

Blue solid line -- strong direct citation of one node by another.

blue heavy broken line -- strong indirect citation connection. These connections were determined by finding an intermediate paper by an earlier nodal author which was cited by a later nodal author.

Blue fine broken lines -- strong indirect citation connection established by finding an intermediate paper by the later nodal author which in turn cites the earlier nodal author.

Fourth overlay (blue) – Coincident weak citation connections -- weak citation connections also coincide with Asimov's description.

Solid line -- implied citation connection where a nodal author refers to the work of an earlier nodal author by text description or through personal communication but not by explicit citation.

Blue broken lines -- weak indirect citation connection established by one intermediate paper by a non-nodal author.

NON-COINCIDENT CITATION CONNECTIONS
YELLOW OVERLAYS 5 & 6

Fifth overlay (yellow) – Non-coincident strong citation connections. Citation connections which do *not* coincide with Asimov's historical connections.

Solid line -- strong direct citation of one node by another

Broken line -- indirect citation connection where connections were determined by finding an intermediate paper by an earlier nodal author which was cited by a later nodal author.

Fine broken line -- indirect citation connection established by finding an intermediate paper by the later nodal author which in turn cites the earlier nodal author.

Sixth overlay (yellow) – Non-coincident weak citation connections. Citation connections which do *not* coincide with Asimov's historical connections.

Solid line -- implied citation connection where a nodal author refers to the work of an earlier nodal author by text description or through personal communication but not by explicit citation.

Broken line -- indirect citation connection established by one intermediate paper by a non-nodal author

COLOR CODES FOR COMBINATIONS OF TRANSPARENCIES

When all transparent overlays are combined or superimposed a complete comparative picture is observed -- both coincidence and non-coincidence of the Asimov historical network and citation network.

The nodes which were *not* reinforced by citation connections stand out as pure red lines. The citation connections which coincide with Asimov's historical connections are purple, that is, a combination of red and blue. The same information is revealed by examining the blue overlays separately.

Citation connections which are not coincident with Asimov's historical connections stand out as pure yellow lines.

The composite of all six overlays reveals those connections established by Asimov alone, by citation data alone, or a combination of the two.

A composite of the top four overlays (third through sixth) represents citation data. However, the reader should keep in mind that the citation connections are those established almost exclusively on the basis of nodal data, not on the basis of locating citation data from all possible sources.

Nodes are indicated by blocks assigned in chronological order. Each block contains the nodal number, nodal author named by Asimov, and the years covered by the nodal work. (Secondary authors are only included in nodes 6, 9, 12, 15 in order to distinguish these nodes from others in which Levene and Fischer are also involved.) The topological display of the nodes is organized so that nodes for broad fields are alligned together. Each broad field has a corner code indicated below:

GENETICS | PROTEIN CHEMISTRY | NUCLEIC ACID CHEMISTRY | VIROLOGY | UNCLASSIFIED | COMBINATION

In some nodes combinations exist. For example, Node 20 is coded both for bacterial genetics and nucleic acid chemistry.

Starting near bottom left one can see the development of protein chemistry. At the center the field of genetics is traced and on the right nucleic acid chemistry. One can see that the various fields coalesce as molecular biology towards the center and top of the network.

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(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

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2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE
"THE USE OF CITATION DATA IN WRITING THE HISTORY OF SCIENCE"

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Final Report; December 31, 1964

5. AUTHOR(S) (Last name, first name, initial)
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7a. TOTAL NO. OF PAGES

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9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

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13. ABSTRACT

A study is reported which tested the hypothesis that citation indexes are useful heuristic tools for the historian. In this approach, the history of science is regarded as a chronological sequence of events in which each new discovery is dependent upon earlier discoveries. Models of history were constructed consisting of chronological maps or topological network diagrams. Two such models were used here. The first is based on the events in the history of DNA as described by Dr. Isaac Asimov in The Genetic Code. The second is based on the bibliographic citation data contained in the documents which are the original published studies of events represented in the Asimov book. The interdependencies of linkages among 40 major events (nodes) included in both network diagrams were mapped and compared. The study confirmed 65% (28 of 43) of the historical dependencies in the Asimov network by corresponding linkages established by citations. In addition, 31 citation connections were found which did not correspond to any historical dependencies noted in The Genetic Code. Eleven of the nodes did not cite any earlier nodal work. Subjectively, these could be interpreted as works which introduced new fundamental information. The analyses, supported by numerous statistical tables and specially constructed citation indexes, show that the original hypothesis is reasonable. Techniques described in this study appear useful in writing histories of science by helping to identify key events, their chronology, their interrelationships, and their relative importance.

DD FORM 1473

Unclassified
Security Classification

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
Asimov						
Bibliographic data						
Citation index						
Data analysis						
Genetic code						
History of science						
Information retrieval						
Molecular biology						
Network diagrams						
Retrieval						
Science Citation Index						

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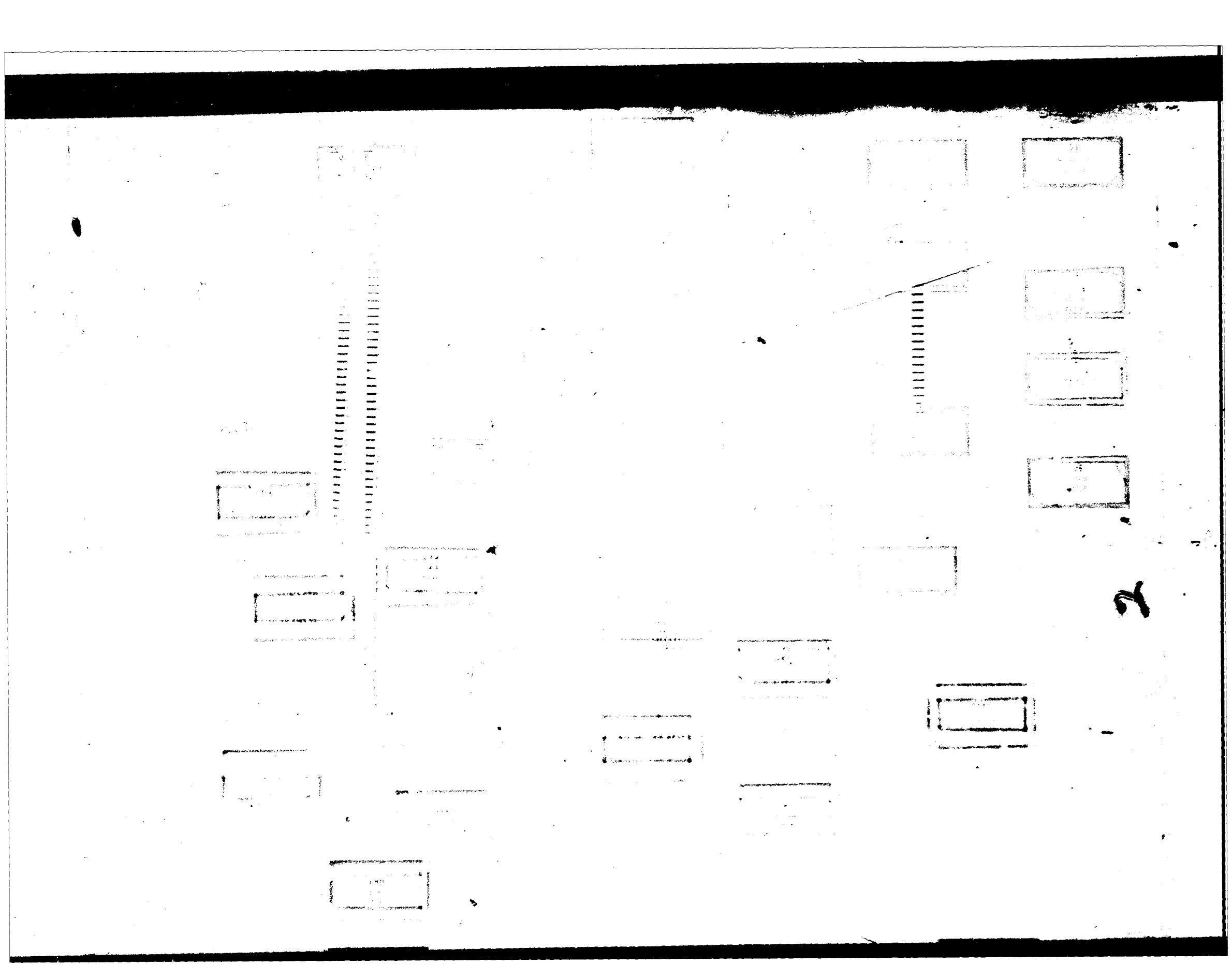

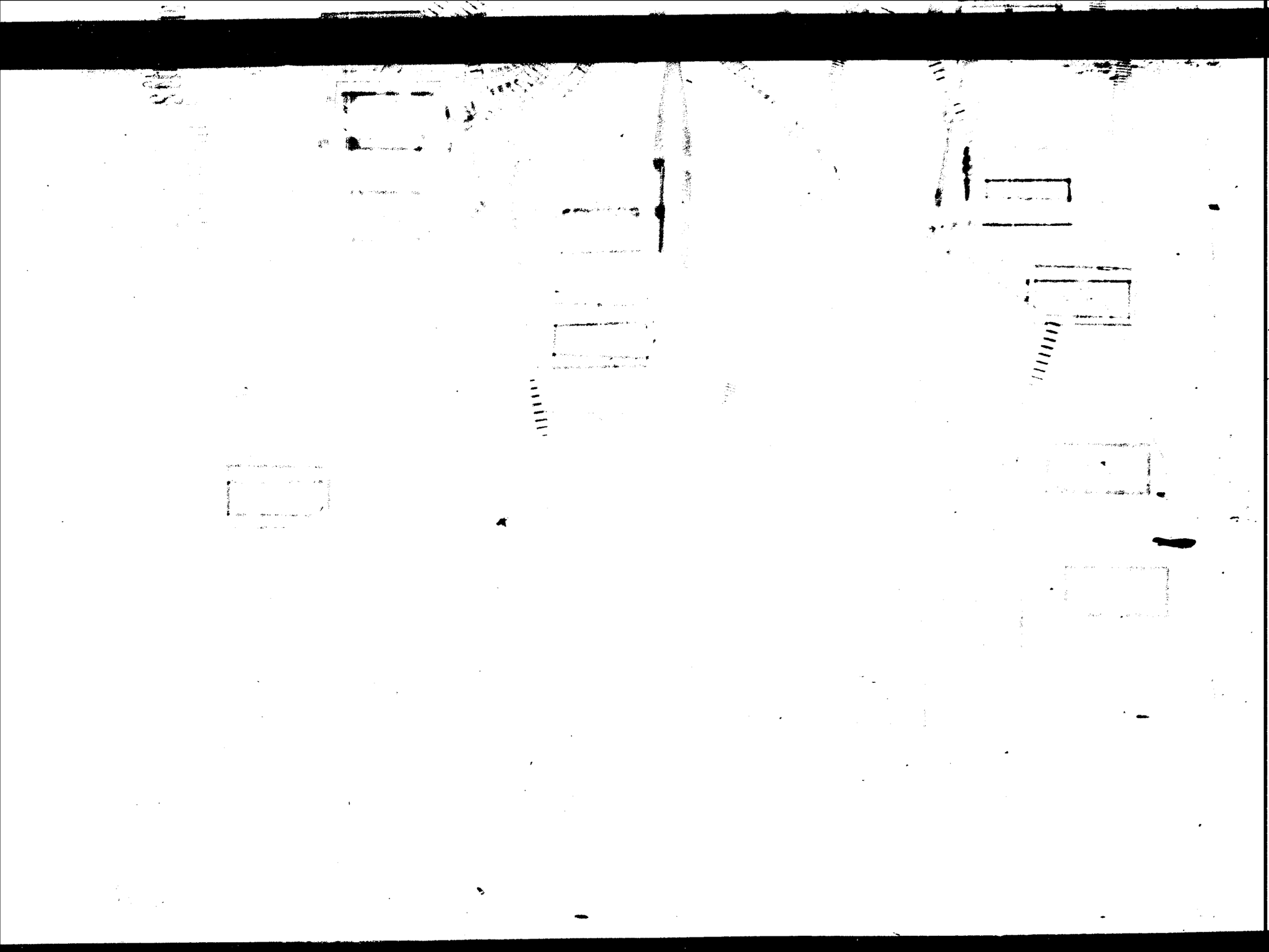

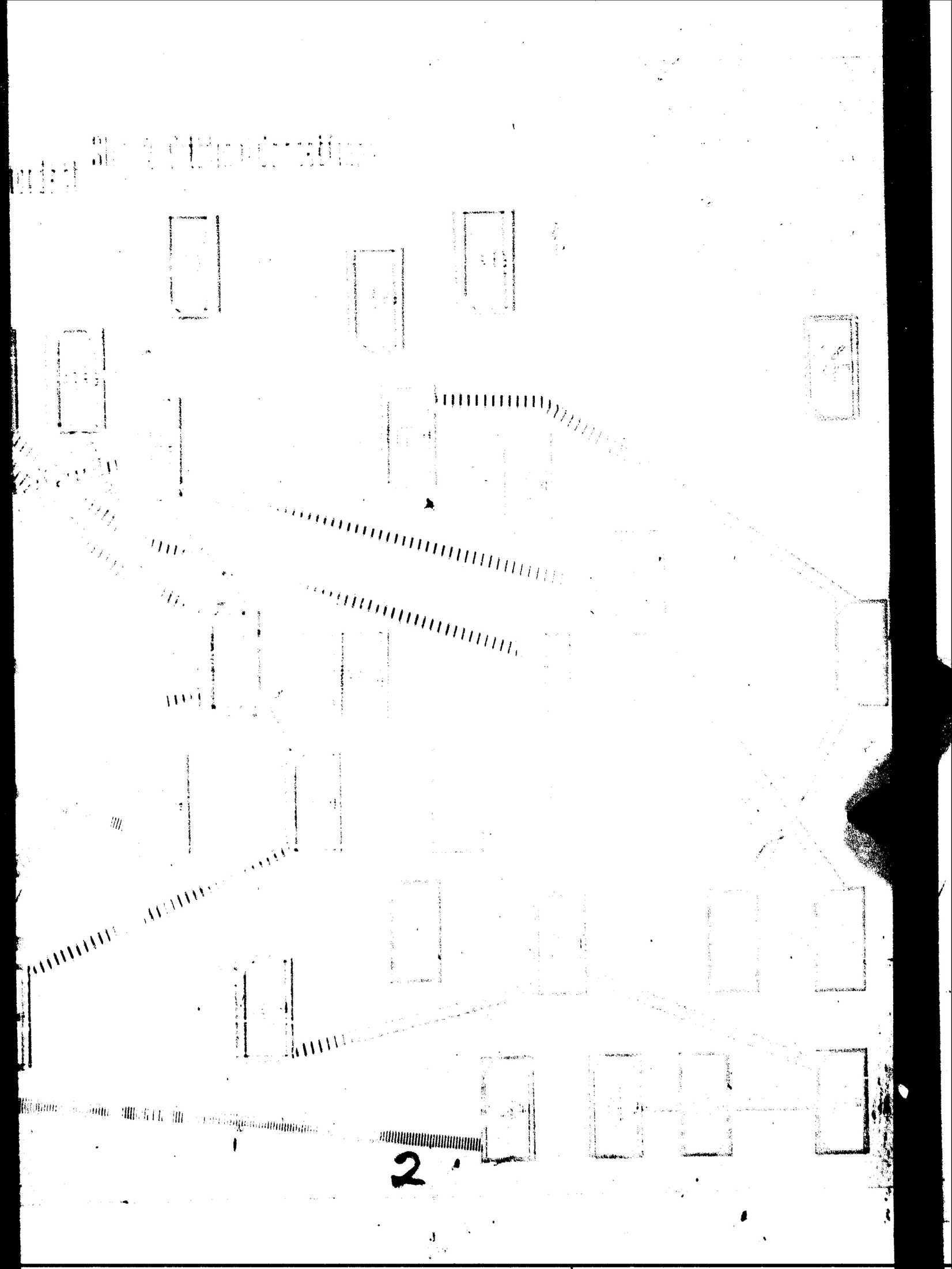

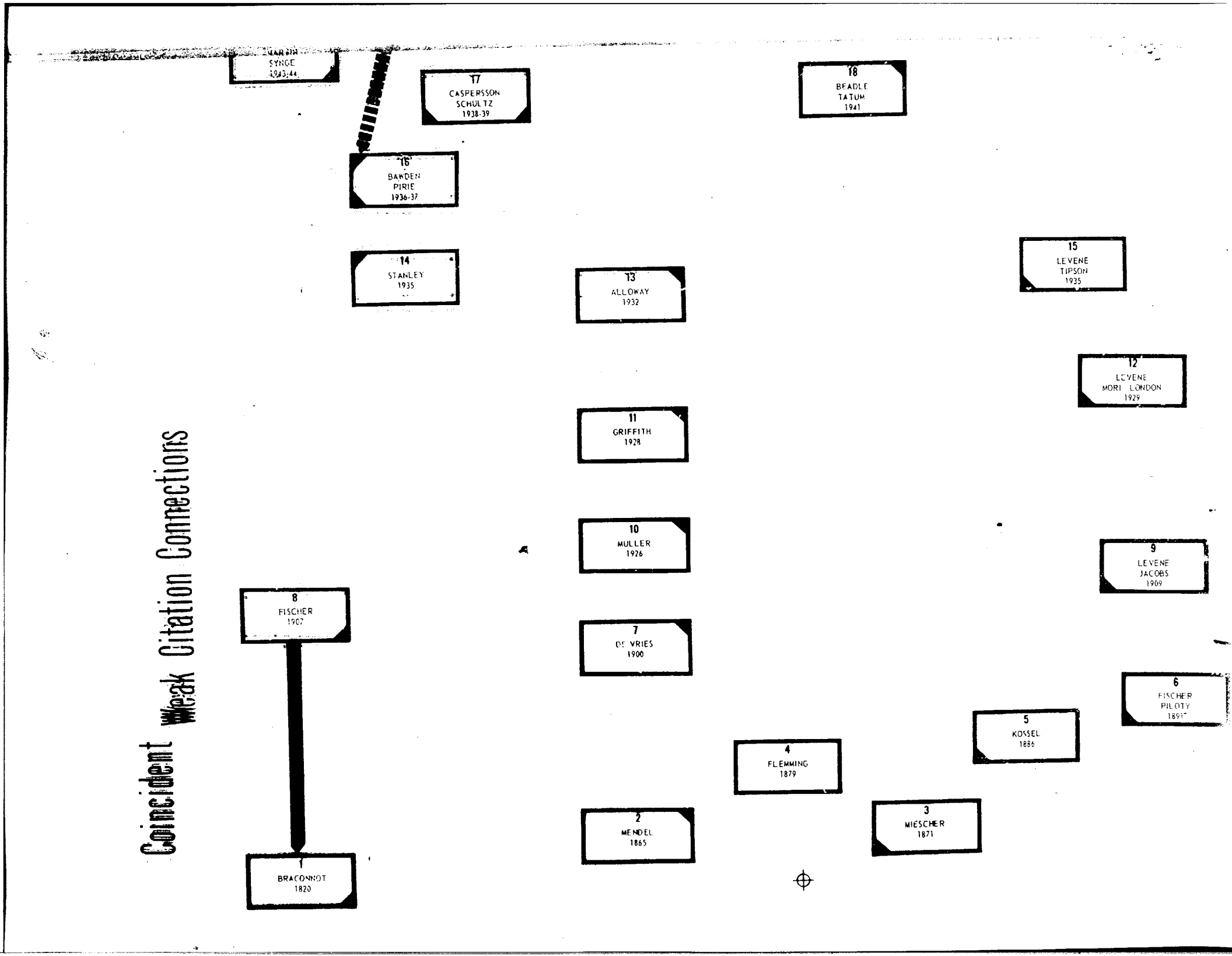
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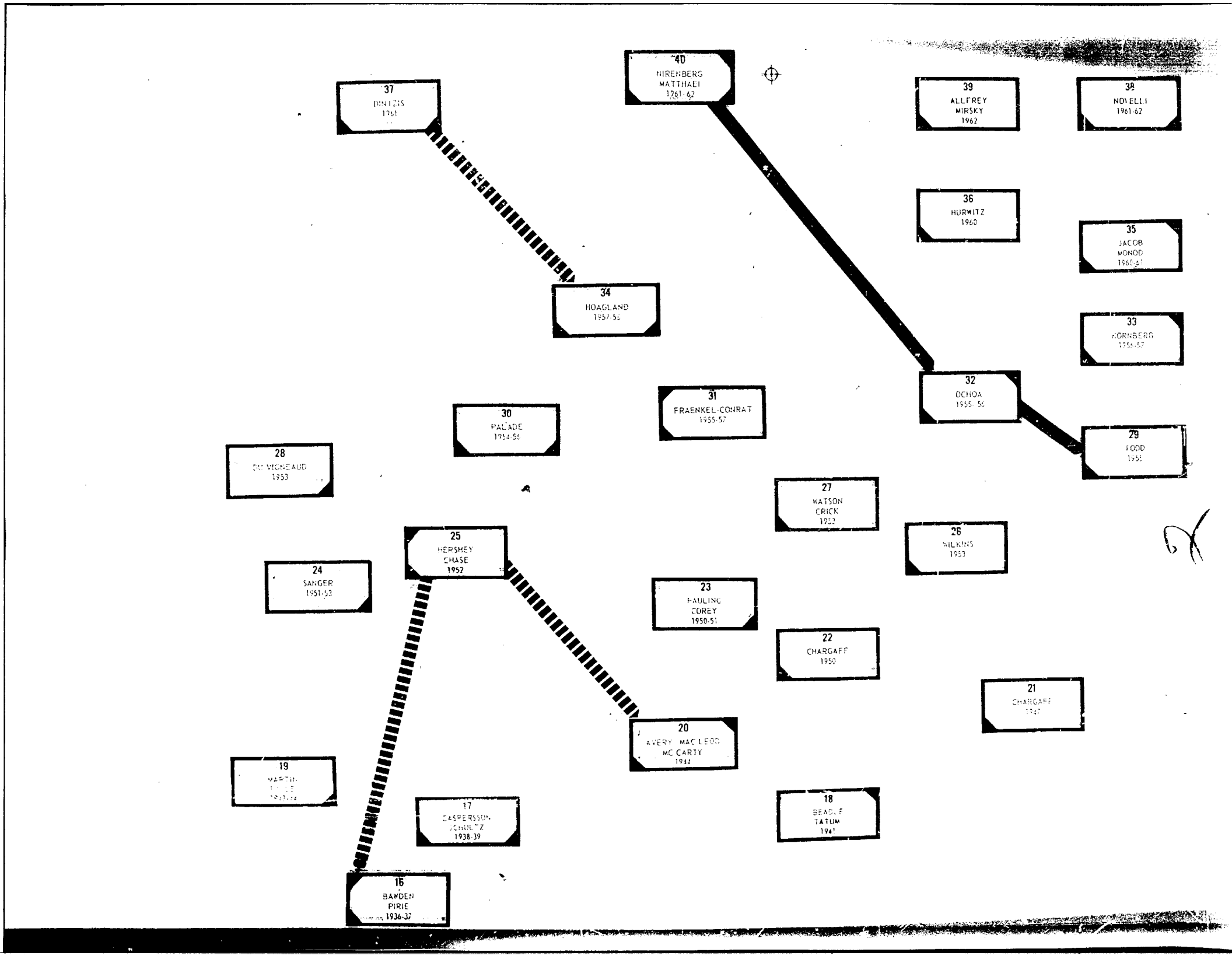
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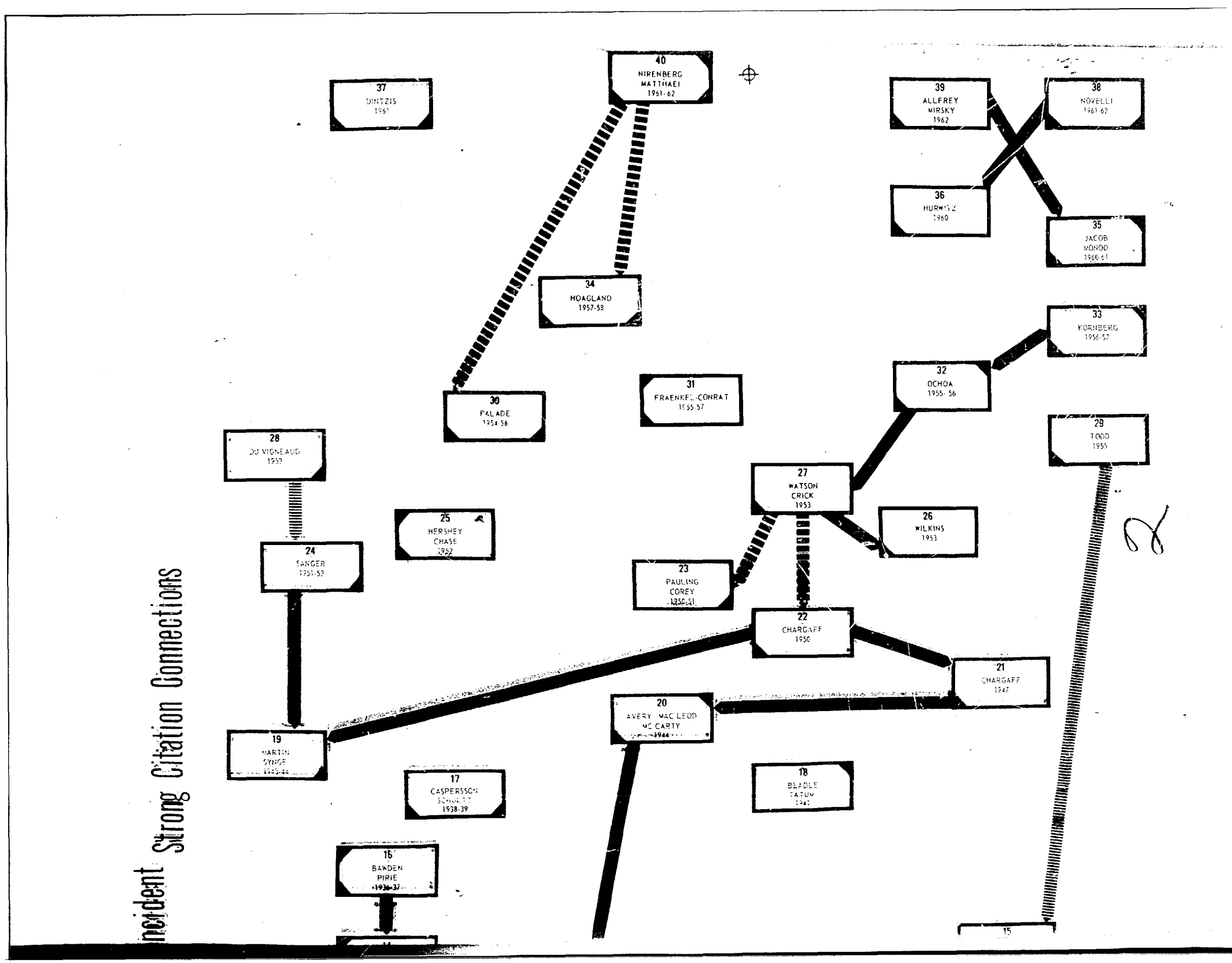
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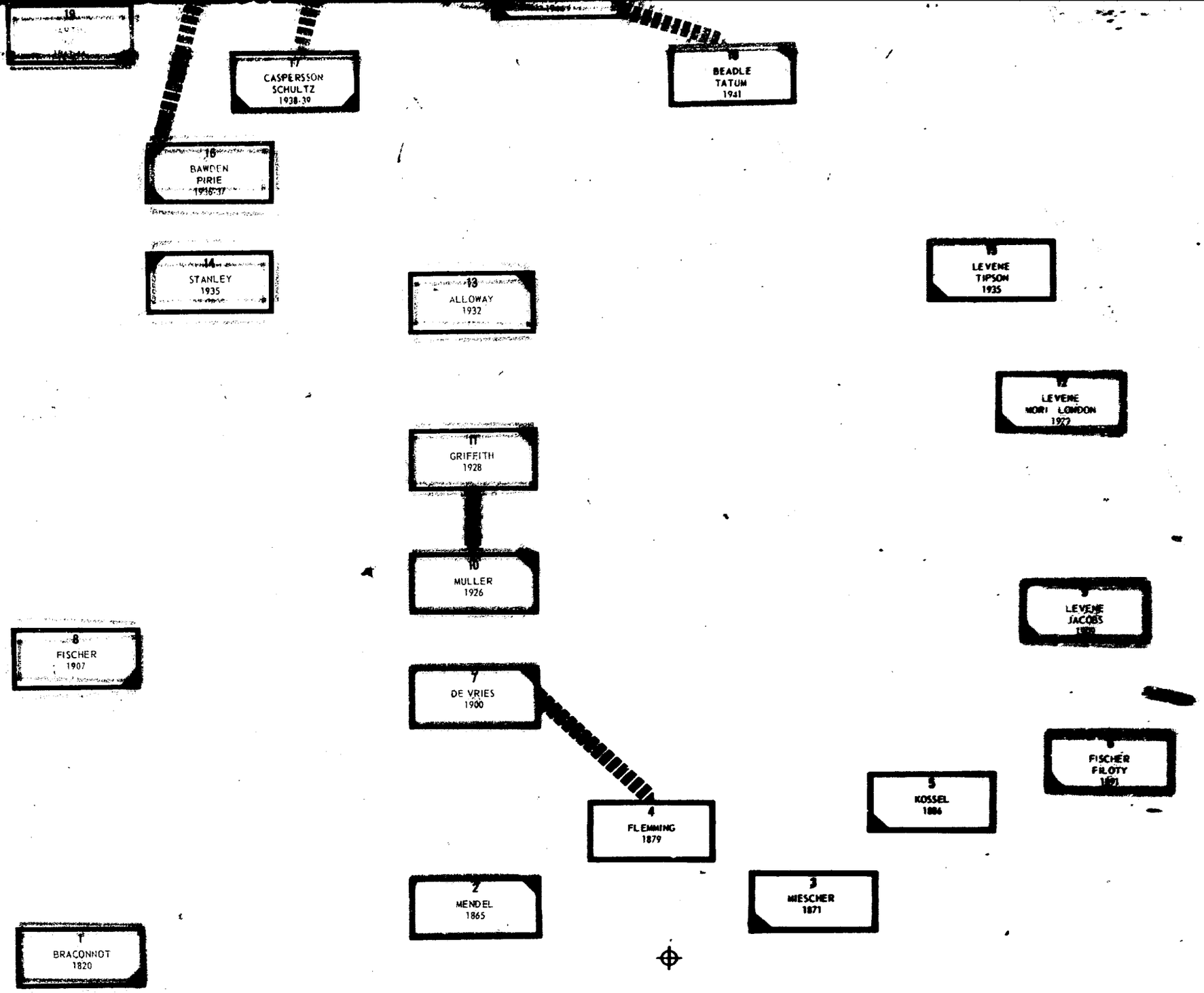
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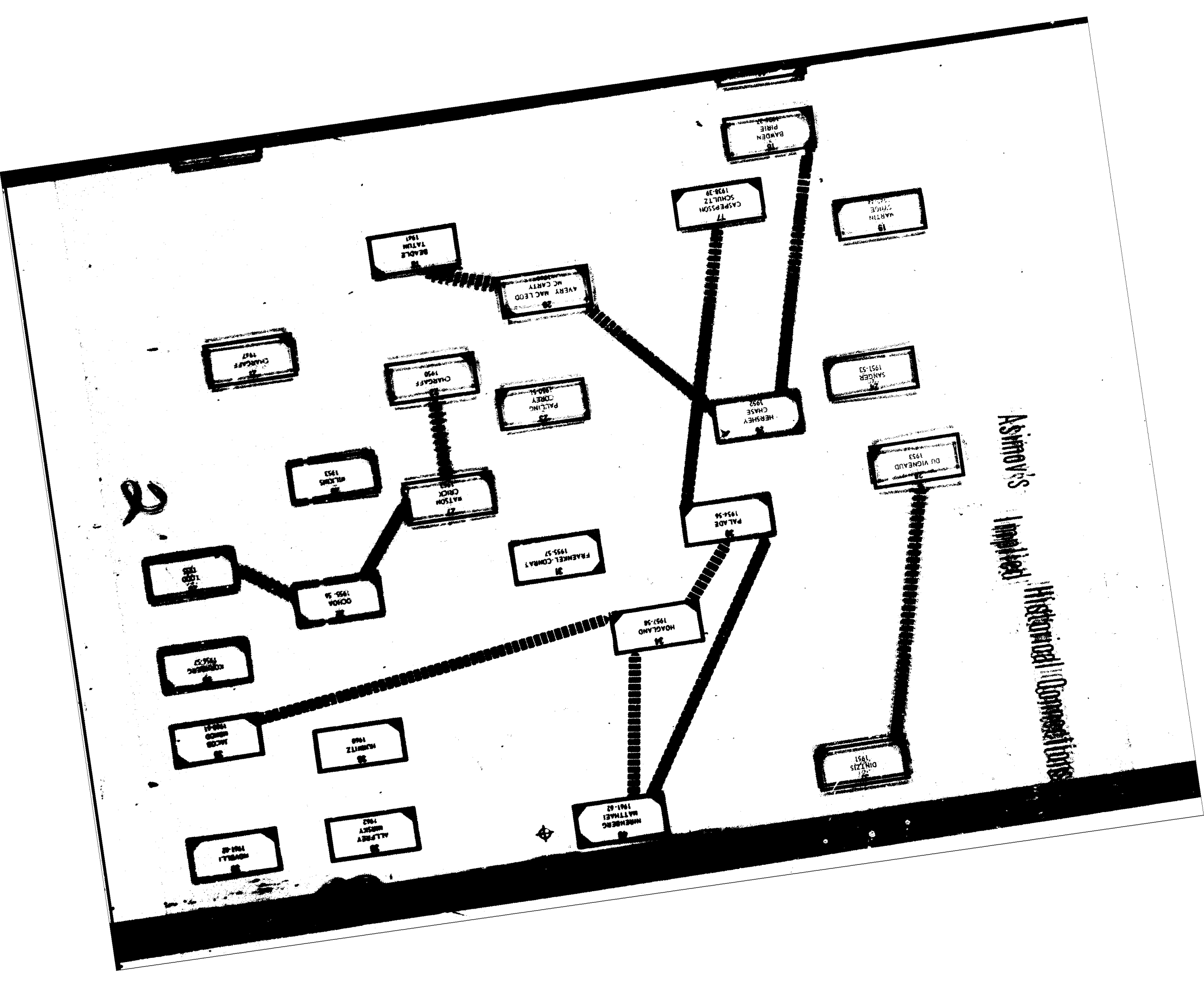
Asimov's
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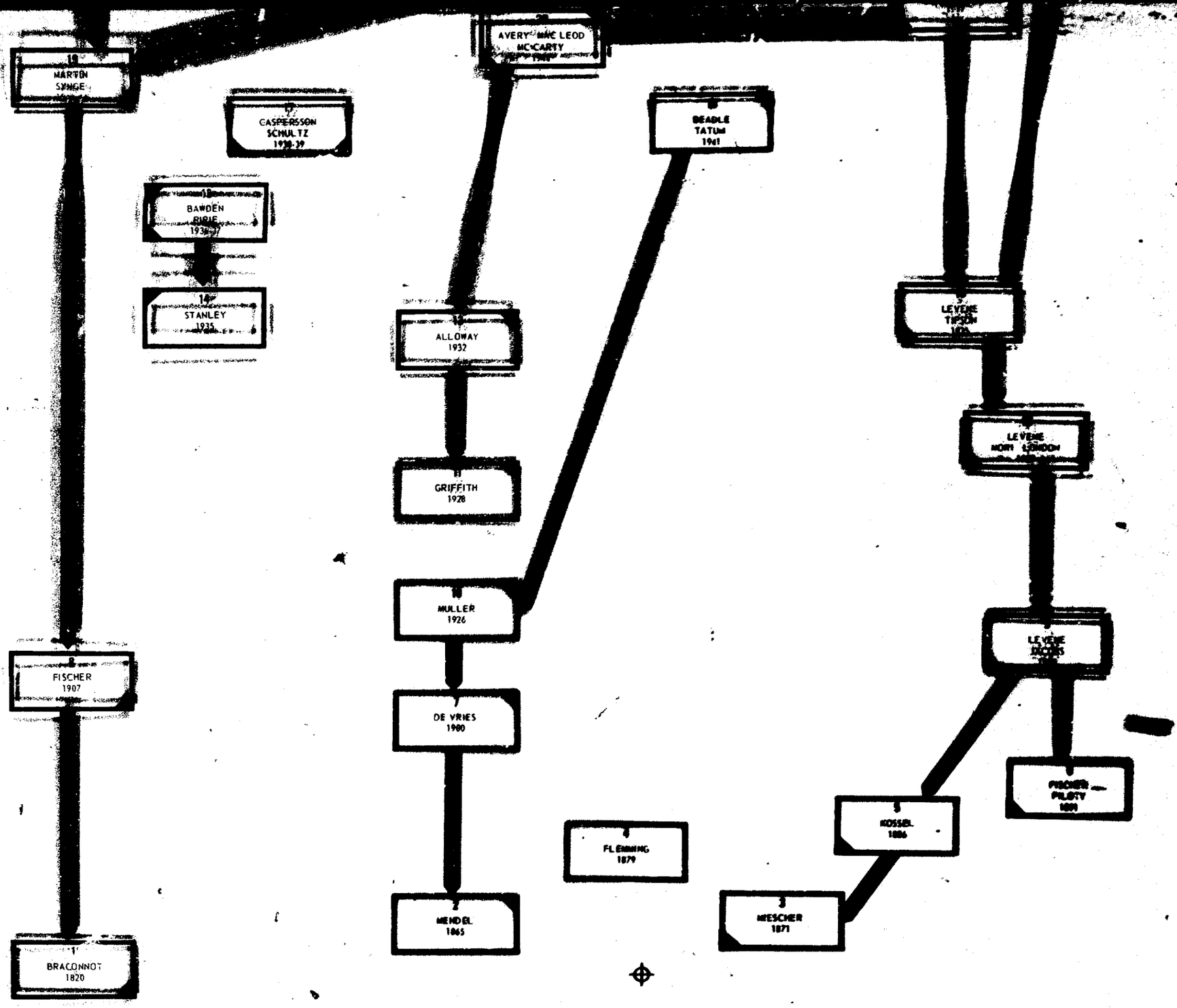
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Asimov's Specified Historical Connections